MICHIGAN

STATE HIGHWAY DEPARTMENT

LANSING

INSTRUCTIONS FOR MAKING SURVEYS AND PLANS

FRANK F. ROGERS, C. E., State Highway Commissioner.
LEROY C. SMITH, Civil Engineer Deputy.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1918

MICHIGAN

STATE HIGHWAY DEPARTMENT

LANSING

INSTRUCTIONS FOR MAKING SURVEYS AND PLANS

FRANK F. ROGERS, C. E., State Highway Commissioner.
LEROY C. SMITH, Civil Engineer Deputy.

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1918

FOREWORD.

This Department has developed the following methods of doing survey and plan work which we believe is best for the purpose, and the object of this book is to acquaint surveyors, or engineers, with those methods.

Our experience has shown to us important things which men with little practice in road work often overlook. It is obviously impossible to treat all of them fully in a book of this sort.

However, if the various standard forms and instructions reproduced in this book be carefully studied by the engineer, he will have no difficulty.

These standard forms and instructions are subject to revision at any time, and, as new methods develop, certain parts of this book may become obsolete. All changes will immediately be brought to the attention of the men whose work is thereby affected.

INTRODUCTION.

The success of our work throughout the State is dependent largely upon the courteous and businesslike manner with which our field men meet the public. Upon your arrival at the place at which the survey is to be made, make it a point to see some member of the County Road Commission, or Township Board (whichever has jurisdiction over the road), talk with them about the work, and follow their suggestions if they are good and not contrary to our instructions, plans or specifications. The desire of the Department is to promote a feeling of good fellowship between local officials and the personnel of the Department. Make them feel that we recognize their share in the work and that this Department is cooperating with them to obtain the best results possible.

The necessity for uniformity of work, and certain other requirements, make it imperative that the instructions following be carefully observed by all men who make surveys and plans for this Department.

In order that the office may be kept in close touch with the field men, daily reports are of vital importance. They should be accurately kept, properly made out with ink, and mailed to the office every day. A report should be made for every day away from the office, including Sundays and holidays. Expenses continue on those days, if work does not. Field men should notify the office of their address, by telegraph or mail, as soon as possible. Give temporary address until permanent one is secured.

Actual transportation and subsistence expenses will be refunded to engineers. Engineers in charge of parties will engage such transportation, make such purchases, and hire such assistance as may be necessary in the prosecution of their work, and will attend to the payment thereof in accordance with the rules governing expense accounts.

RULES OF BOARD OF STATE AUDITORS.

1. All accounts must be rendered in triplicate on the blanks furnished by the Board of Auditors, one on a white sheet, one on a yellow sheet, and one on a pink sheet. The white and yellow sheets must be made out in ink, (or on a typewriter), each sheet properly footed, and the notarial affidavit executed and the receipt signed on the outside. The Notary Public fee must not be placed in the account.

2. The proper date for rendering an expense claim is governed by the meeting of the Board of Auditors. They meet on the last Wednesday of each month and the Wednesday preceding the last by two weeks. Claims must be in this office on Monday before Wednesday of the Board meeting.

3. Give your address as Lansing unless permanently located elsewhere. If the account is not to include salary, draw a line through the words "*services and.*"

4. Make all claims for expenses in the order in which such expenses are incurred.

5. Each claim should be fully itemized, such as: "Phone, Vassar to Commissioner who failed to meet train, 55c." "Telegram, Sanford to Contractor at Saginaw, making appointment, 25c."

6. Give name of hotel at which accommodations are had, stating date and time of arrival and departure. Where room only at hotel is had, the claim should so state.

7. Give name of restaurant, stating the meal, breakfast, dinner or supper, and cost of each.

8. Do not charge board in advance of time covered by this claim.

9. For livery charges give distance traveled one way and state to what place or townships, as: "Livery, Owosso to Corunna, with instruments, one mile, $1.50." Do not simply state, "Livery," and refer to receipt number.

10. Receipt should be taken on regular receipt blanks for all expenses of one dollar or more, except railroad fares and hotel bills.

11. In traveling, give time and place of departure, name of road traveling on, and time and place of arrival, as: "Lansing, 4:58 a. m., Grand Trunk, Detroit, 7:30 a. m."

12. All expenses out of the ordinary should be fully explained either by letter accompanying the claim or otherwise.

13. The pink blank is for use of this office, and is not notaried. It provides on the back of the sheet for a distribution of expense incurred and this distribution should always be made when making accounts.

GENERAL.

All instruments are to be secured from the instrument room only on requisition. The engineer is held responsible for the safety and care of them while in his possession. Do not express transits or levels unless properly boxed, and then only when absolutely necessary. They should be carried as hand baggage and not checked. Postage stamps, stationery, report blanks, note paper, pencils, etc., are all furnished and are secured without requisition.

No letters on official business shall be written by surveyors to anyone but the office. All such letters shall be addressed to ths Department, attention of ..... This Department prohibits any surveyor from giving any written communication to any local official or contractor concerning any work or in any way relating to the business of the Department.

It is to the interest of each engineer, as well as to the Department, that field parties be well organized and just large enough to do the work economically. While it is not the desire of the Department that engineers take any unnecessary time in making surveys, it most emphatically objects to such haste the work suffers in accuracy and completeness thereby. A reputation for speed alone is not as desirable, from the office view-point, as one for accuracy and completeness of notes.

SURVEYS.

Surveys made by this Department are for three classes of road; Trunk Line, Assessment District, and Federal Aid. The only differences between them are in stationing and staking. In trunk line surveys a new station zero is taken whenever a civil township is passed. In the other two the stationing progresses from one end of the survey to the other. In trunk line and assessment district roads there must be two lines of hubs and markers. In Federal Aid roads only one line of hubs and markers need be set. In all cases every angle point must be monumented and accurately witnessed. It might become necessary to reset a monument, especially on Federal Aid roads, and without accurate witnesses this could not be done.

When assigned to a survey the first thing to be done before leaving the office is to become familiar with the location of the survey, its relation to previous surveys, and see that proper information for tying onto previous surveys is obtained. Previous datums should be continued on new surveys wherever possible. The engineer will be held responsible for proper connections. Before starting work on the ground, the engineer should provide himself with all the available information regarding Government corners to which the survey will be tied. This information may be obtained:

1. By calling on the register of deeds of the county and copying the original survey notes.
2. By getting witnesses from the county surveyor, or other local surveyors, who may be doing work regularly in the county.
3. By questioning all the adjacent land owners and old settlers in the vicinity of the work. In this case one gets considerable information of a more or less inaccurate nature. This should be sifted to the most probable facts.

Before any staking is done, the engineer, with one or two assistants, should go over the line and uncover the corners to which the survey is to be tied. A corner is not lost so long as its position can be determined by any kind of evidence without making a relocation survey. Do not be too easily discouraged if the corners are not readily found. If it takes a day of steady digging to uncover an important corner, this Department will be better pleased if it is found and the survey properly tied to it. If important corners do not exist on the ground they should be re-established according to the rules of the U. S. Gov. Land Survey. This is important and no corner should be set permanently which is not in accordance with the U. S. Gov. Survey, if there is any chance of its being taken as the U. S. Gov. corner by the public.

The corner should be placed within the best known limits although it may not be the exact spot. However, the engineer must be certain of the authenticity of the evidence.

First, in the re-location of lost corners a copy of the U. S. Gov. Field notes must be secured. These can be obtained usually by telephoning

to the Register of Deeds or County Surveyor, or by writing to the Department.

In general, retrace the known lines of the description and find how the lengths and directions of these lines by your survey, agree with those of the same lines laid down in the original description. Then run the unknown lines and place the lost corners so that they will bear the same relation to the known lines and corners as they are required to do by the description of the original survey. That is, as the original field note distance between the selected known corners is to the new measure of said distance so is the original field note length of any part of the line to the required new measure thereof.

(1). To restore corners on base lines, standard parallels and range lines: Restore the lost corners in line between the nearest known corners on the same line and at a distance proportional to those laid down in the field notes of U. S. Gov. Survey.

(2). Lost closing section corners upon a township or range line, where closing distance from the adjacent corners is not given should be restored by prolonging the known position of the line to its intersection with the township or range line.

(3). Lost interior section corners (corners not on town or range lines) should be restored at distances from nearest known corners north, south, east and west, proportional to those laid down in the field notes of the original survey.

(4). Lost township corners, when common to four townships are to be restored in a similar manner to Rule 3. When common to only two townships, according to Rule 1.

(5). Lost quarter section corners are to be restored in line between section corners and at distances between them proportional to those returned in the field notes of the government survey. This rule is very important when applied to fractional sections. In all cases the extra length or shortage of line over or under the U. S. Government length for line shall be divided proportionally.

The thing to find out is not where the corner or line ought to have been, but where it actually was. The engineer should remember that he cannot correct errors in the original survey.

In the subdivision survey of a section the centre of the section can only be set at the intersection of quarter lines. (See Chap. XI of Hodgeman's Land Surveying.)

Never set a center line monument so close to a Government corner that it may be mistaken for the true corner. The road center line should be tied to section corners by distance and bearing accurately enough so that it could be relocated from them if necessary. A description of every Government corner uncovered, together with accurate witnesses, should be noted. New monuments shall consist of iron pipe not less than one inch in diameter and not less than three feet long, buried beneath future excavation and well braced with stones. All angle points shall be so monumented, and witnessed. Where a survey begins, or ends, at, or crosses a civil township line, that line must be carefully intersected with the center line and monumented unless too close to a Government corner when a wooden stake should be driven and carefully referenced to the true corner. The same is true of corporate limits of cities and villages.

While looking up corners the engineer can get the lay of the land, and, if the location is difficult, pick out the most suitable center line and temporarily mark it The time is well spent on this preliminary location for the staking party is not delayed while the engineer is deciding which line to choose. On section line roads, the center line should follow the section line precisely, deviating from it only to save large shade trees, to take advantage of existing earthwork, or to avoid features which would be detrimental to the future road. Where practicable the road center line should be centered on large culverts or bridges which are in such condition and location as not to need replacement when the road is built. On angling roads, the engineer should so locate as to do as little damage as possible to adjoining property owners, and at the same time provide good curves with long sight-tangents. The problem of location is one that should be carefully studied. One can, for instance, often save considerable side earthwork if the centerline location is properly chosen. By estimating the most probable amount of cut and fill at the centerline and figuring the point where the outside slope will intersect the surface of the ground the amount of side earthwork is easily estimated in width. The district engineer should be consulted on all difficult problems.

For the purposes of construction the centerline should be permanently marked at each hundred foot point, by two hubs for Trunk Line and assessment district surveys, and by one hub on Federal Aid surveys. These hubs are set uniformly 25 feet from, measured at right angles to, the centerline. Whenever it is necessary to set hubs at other distances those distances should be carefully noted in the transit book. The hubs are not to be smaller than 1″ x 1½″ x 12″, and driven to ½″ above the ground. A marker, 1″ x 3″ x 30″ shall be set about four inches back of the hub with the wide surface facing the road. The station number shall be clearly written on the face of the marker with red keel.

A regular railroad curve without spiral shall be run in all cases where the deflection of the centerline is 5° or over. These curves should have as long a radius as the conditions will permit. At right angle turns the external shall be as long as possible without crowding the road ditch off the right of way. In no case shall the radius of any curve be less than 66 feet. The points of tangency of the curve should each be marked by a substantial hub driven on the center line and should also be side-staked. When side-staking curves, care should be taken to set the stakes on radial lines at the station points.

When curves of less than 100 feet radius are to be put in, it is often easier to find the center of the curve and swing it in with two tapes.

The length of chord used depends on the degree of curve chosen, as follows:

Degree of Curve	Length of Chord
8° or less	100′
8° 10′ to 16° inclusive	50′
16° 10′ to 32° inclusive	25′
32° 10′ or more	10′

When using chords of 10 feet on curves whose deflection angle is over 90° the usual formulæ for figuring curves will not give the correct results. An exsecant formula must be used. This Department publishes

STANDARD BENCH

+S	HI	-S	Elev.
			875.30
8.86	884.16		
		5.98	878.18
0.38	878.56		
		8.61	869.95
3.41	873.36		
		4.15	869.21

CULVERT

Sta.	Size	Length	Condition
76+52	1'(high) x 1'(Span)	30 Ft.	Bad
78+40	14"	19"	"
108+16	1.5'(high) x 1.5(Span)	41 "	Good
175+30	4' " 6' "	78	Bad

Sta. to Sta		Surface Material	Sub Soil	
0	20	Sand & Gravel	Sand & Gravel	
20	31	Clay & Gravel	Clay 2' down	
31	40	Clay	Wet Clay	
40	182	Macadam 6" poor	Clay & Gravel	
182	184	Gravel	Muck	

FORM

LEVELS

Description		
B.M. #5	Spike in tel. pole	19' L. of Sta. 5+10
T.P.		
B.M. #6	Spike in tel. pole	26' L. Sta. 16+30

NOTES

Materials	Notes
Stone sides - flag top	Build new 1.5x2
Vit. pipe	Remove
Stone arch	Retain
Stone sides. timber top	Build new 4'x6'

Foundation Recommendations
Needs good subdrainage
Resurface only
Boq. Fill sides with gravel. Average
height of present fill 2' above water.

PLATE 1

tables for use in running curves. Always check the location of a curve by measuring out from the center point the half-width of the turnpike plus the ditch width and see that it does not interfere with private property. The forward chaining should be done around the curve and not on the tangent.

The data for the curve should be set down in a concise table near the station of the P. I. in the transit book.

See Allen's or Searle's Handbook for the Railroad method of staking a curve.

The meridian direction should be noted on each page of the field book as it aids the draftsman in his work. The needle should be read at each set up both before and after turning the deflection so that it may act as a check on the transit angle. The reading should be noted in the book and marked "mag."

After the alignment of a road has been marked the levels shall be run with an engineers level, or transit without stadia hairs. Bench levels shall be run first and benches shall be established 1,000 feet to 1,500 feet apart. Other benches shall be set on each side of a bridge and not more than 500 feet from the edge of stream. All benches must be incorporated in the level circuit whenever read upon. After the benches are set the profile and cross-section levels shall be run, checking on each bench as it is passed and always making a turning point of the bench. The cross section notes must be complete enough so that the volume of earthwork may be computed from them. It is useless to describe here the details of taking these levels, but the engineer will do well to make a careful study of this work and see that he gets all the information needed. Upon these notes depend the estimates of earthwork, and erroneous estimates work great harm in letting contracts.

The datum of the U. S. G. S. should be used wherever a U. S. G. S. bench may be had. There is a list of such bench marks in the office and it should be consulted before going on a job.

Readings taken to the nearest 0.1 ft. are accurate enough for all ground shots. Turning points and benches should be read to the nearest 0.01 ft.

Whenever a culvert or bridge is encountered the elevation of the floor, bridge seat, high water, normal water, bed of stream, (or invert), and slope of stream must be obtained. Where the river is wide a profile across the river bottom must be run on each side of the bridge or bridge site far enough away from the bridge to get away from all holes or washes.

When new culverts are recommended by a surveyor a cross section of the road at that point must be taken, also readings 100 feet each side of the center line to show that there is sufficient outlet for the culvert.

At a cross road the drainage and the slope of the traveled road are not always in the same direction. Therefore, the direction of the drainage should be carefully recorded, as well as the slope of the cross road on both sides of the survey. 300 feet is far enough to run to determine these slopes.

When a railroad parallels and lies without the right of way and is distant less than 150 feet from the center line an elevation of top of rail shall be taken at least every 500 feet. When such railroad lies within the right of way, an elevation of top of rail shall be taken at each station.

When a railroad crosses the survey, the elevation of top of rail shall be taken at the intersection with the center line.

Levels are of little value unless they check. By running the bench levels first and figuring the height of instrument and elevation of turning point of each "set up" it is a simple matter to see that they do check. All notes are checked with an adding machine upon arrival at the office so that arithmetical mistakes are quickly detected. An erasure of a rod reading, especially in a note book in which there is an error, at once casts doubt over the whole work. If there has been a mistake in setting down a rod reading don't erase but draw a line through it and write the correct rod reading above it.

In country which is not rough, an error of 0.1 foot per mile is allowable in closure. In rougher country a larger error is permissible as the number of "set ups" increases. But in no case shall an error of closure be more than 0.2 foot per mile.

Good leveling cannot be done when the distance from the instrument to the rod is more than 400 feet for any reading. To obviate instrumental errors it is advisableto take turning point shots equidistant from the instrument. It is the duty of the engineer to keep his instrument bubbles in adjustment. Cleaning of bearings of instruments is to be done only in the office.

All notes on topography and culture are to be recorded on the same page as the transit notes. The objects are to be located from the center line by the method of right angle offsets. Objects as far away as 200 feet from the center line should be noted, as they have considerable bearing on construction. The topography shall consist of streams, swamps, hills, trees, bushes, etc. Culture consists of culverts, side fences, buildings, railroads, guard rail, farm line fences, telephone, telegraph, and transmission lines, farm entrances, etc. On Assessment District and Federal Aid surveys note the location of one important entrance for each group of farm buildings. Note the plus station of each side of a building, together with its distance from the center line (the latter may be estimated, if without the right of way). The plus of property line fences should be noted at the point where the same, if produced, would intersect the center line. Distances from the center line to side fences should be carefully measured, more especially at curves and angle points. In short, the location of all the works of man should be carefully noted so that they may be readily and accurately plotted on the plan.

STANDARD
CONTINUOUS

+S	H.I.	-S	Elev.	Sta.	L.Hub	I.
4.79	87.77	3.47	82.98	T.P. on 25' stump		
				46	9.7	20/9.1
					78.1	78.7
				47	11.1	20/11.2
					76.7	76.6
				48	8.9	
					78.9	
				49	7.5	
10.65	90.97	7.45	80.32		80.3	
				50	11.4	16/10.3
					79.6	80.7
				51	10.8	16.0/11.0
					80.2	80.0
				52	10.9	
					80.1	
				+50	Culvert (tile)	
		2.85	88.12	BM. #4		

FORM

LEVEL NOTES

Apr. 5, '15
O.H. Vergeson
Rod R. Murray
Tape E. Young

I	I	℄	I	I	I	E. Hub 25'	
5 / 4.7		4.7		7 / 5.0	19 / 12.6	13.3	
83.1		83.1		82.8	75.2	74.5	
	6 / 4.9	5.0	6 / 5.0		17 / 12.3	12.8	
	82.9	82.8	82.8		75.5	75.0	
14 / 8.1	5 / 4.9	4.6		8.0 / 4.7	17 / 10.3	11.5	
79.7	82.9	83.2		83.1	77.5	76.3	
14 / 7.5		7.1			14 / 8.3	7.6	
80.3		80.7			79.5	80.2	
14 / 11.4		10.4		12 / 11.5	14 / 10.6	10.6	
79.6		80.6		79.5	80.4	80.4	
15 / 11.6		11.2		13 / 11.2		10.9	
79.4		79.8		79.8		80.1	
V3 / 10.9	7 / 10.0	10.0	6.0 / 10.0	14 / 11.2	19 / 11.1	21 / 10.0	9.9
80.1	81.0	81.0	81.0	79.8	79.9	81.0	81.1
80 D.B / 9.7	9 F.L. / 10.1	6.7	8 F.L. / 10.2	100 D.B / 10.7			
81.3	80.9	843	80.8	80.3			
Spike in Tel. pole 25' L. of Sta. 52+80							
						PLATE 11	

STANDARD
TRANSIT & TOPOGRAPHY

Defl. Bearing

30

29

28

E = 12.9
Δ = 27°25'L.
T = 107.5
D = 13°
L = 210.8
Ch.L = 50.0
P.C. = 25+92.5
P.I = 22+00
P.T = 28+03.3
R = 441.7

27 N. 55° W. (Mag.)
27° 25'L. N. 55°10'W. (Comp.)

26

L. Kelley Inst.
25 R. James Flag
T. Jones H. Chain
R. Wood R. Chain

24 Wednesday June 16, '15 E. Morrison Notes

Tuesday June 15, '15 Rain all day

23 N. 28° W. (Mag.)
+80 12°45'L. N. 27°45'W (Forward tangent)

No curve on account bridge

22 7°30'L. N. 15°00'W
N. 15° W. (Mag.)

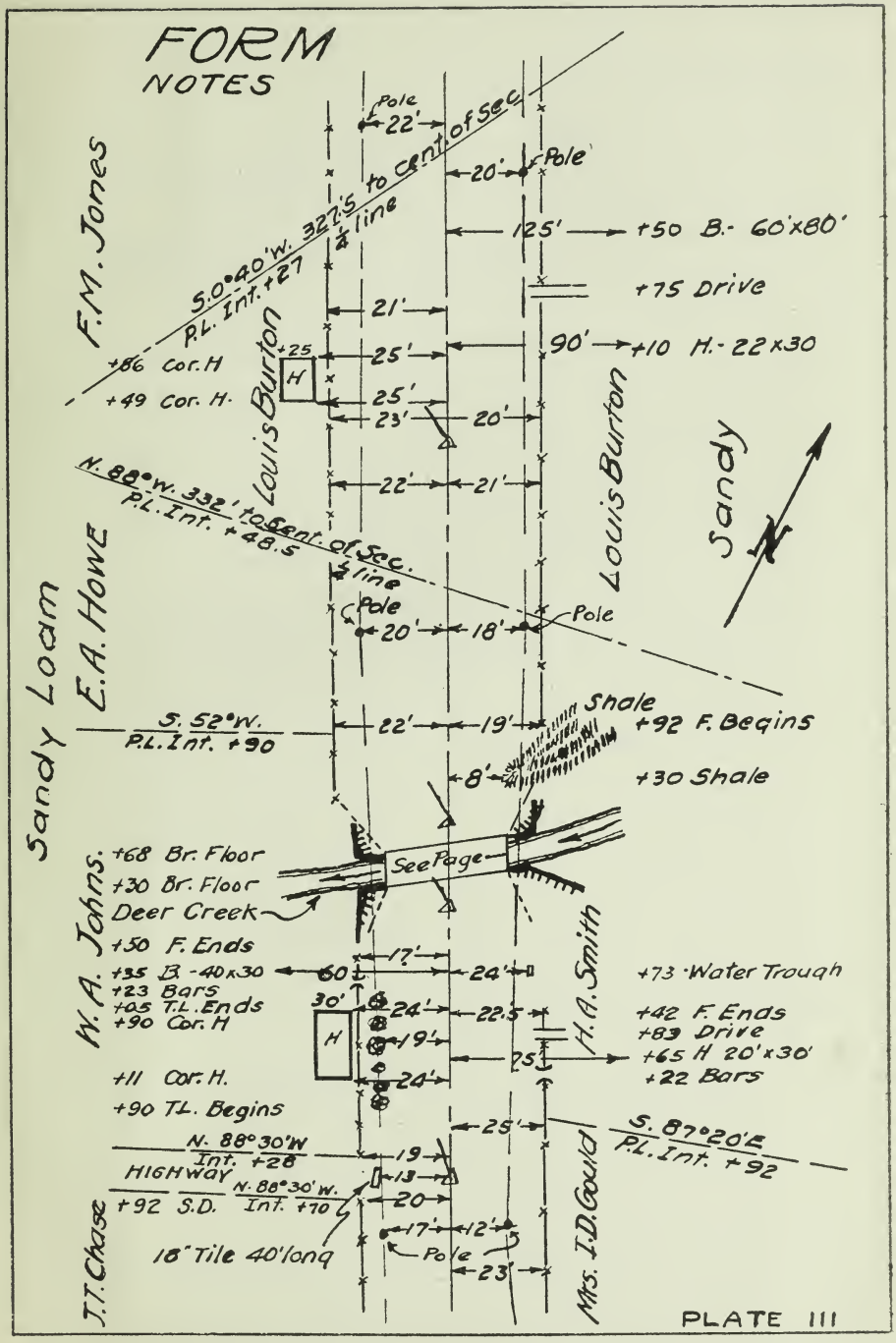
21

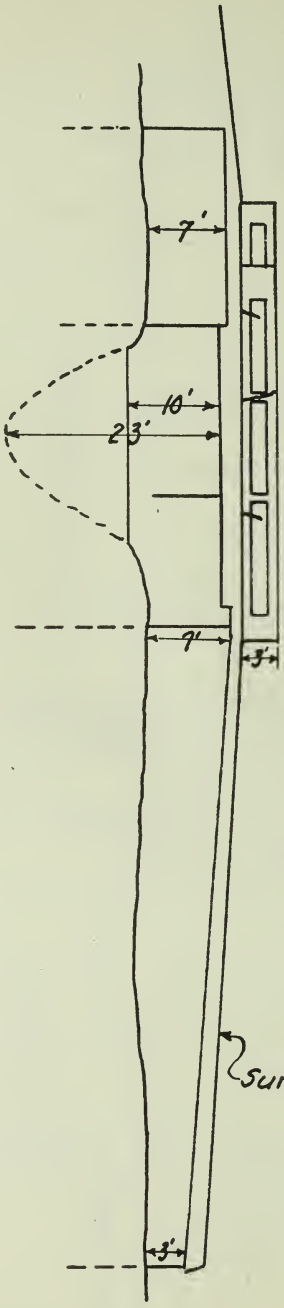
20

E = 3.49
Δ = 8°00'L
T = 100.16
D = 4°00'
L = 200.00
Ch.L = 50'
P.C = 17+99.84
P.I = 19+00
P.T = 19+99.84
R = 1432.7

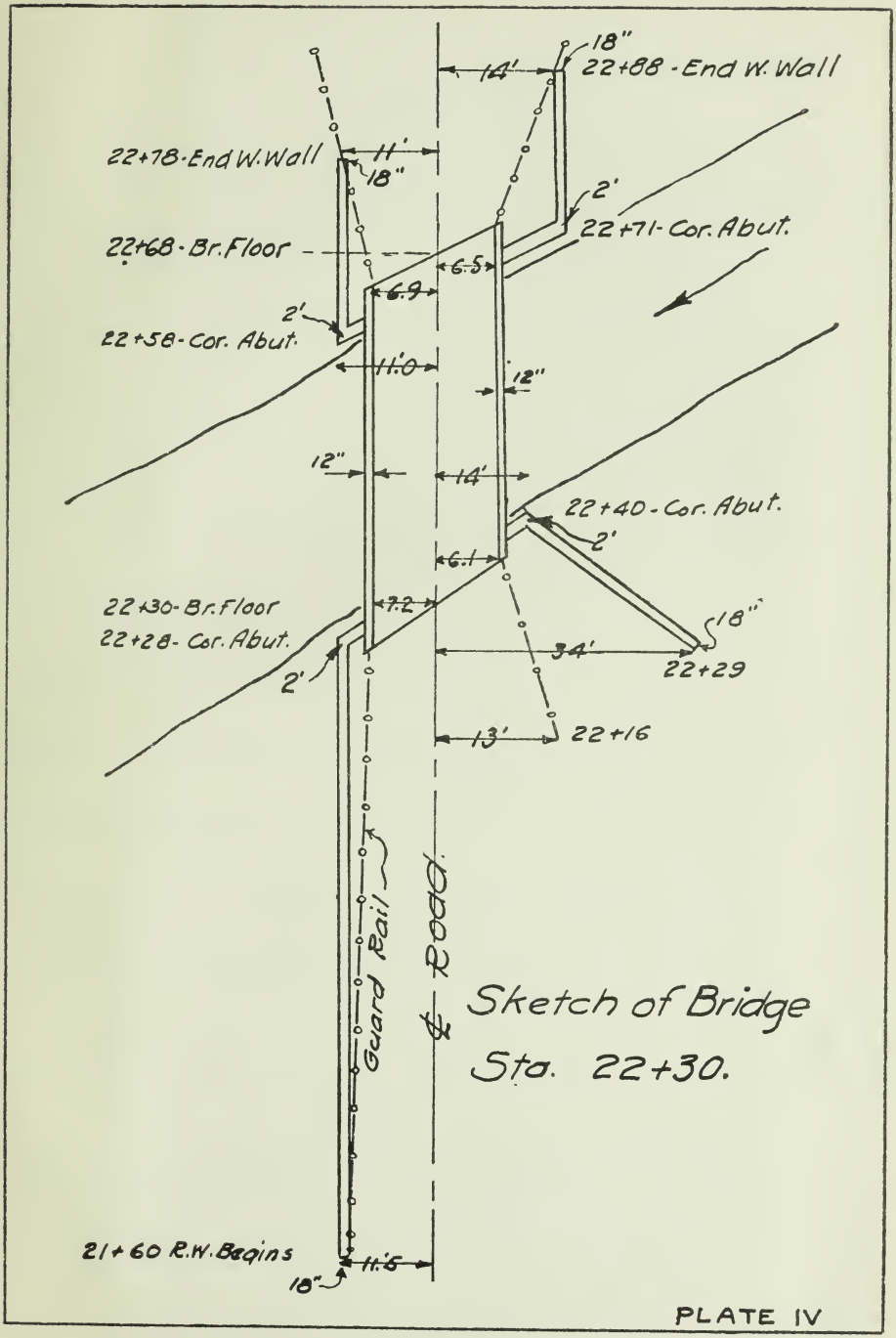
19 N. 8° W. (Mag.)
8°00'L. N. 8°30'W. (Comp.)

18


FORM
NOTES
F.M. Jones
Louis Burton
Louis Burton
Sandy
E.A. Howe
Sandy Loam
W.A. Johns.
H.A. Smith
T.T. Chase
Mrs. I.D. Gould
Pole
22'
20'
Pole
S.0°40'W. 327.5 to Cent. of Sec. ¼ line
P.L. Int. +27
125'
+50 B.- 60'x80'
+75 Drive
21'
90'
+10 H.- 22'x30'
+25
+86 Cor. H
+49 Cor. H.
25'
25'
23'
20'
22'
21'
N. 88°W. 332' to Cent. of Sec. ¼ line
P.L. Int. +48.5
Pole
20'
18'
Pole
S. 52°W.
P.L. Int. +90
22'
19'
Shale
+92 F. Begins
8'
+30 Shale
+68 Br. Floor
+30 Br. Floor
Deer Creek
See Page
+50 F. Ends
+35 B.-40x30
+23 Bars
+05 T.L. Ends
+90 Cor. H
60'
17'
24'
30'
24'
19'
22.5
25'
+73 Water Trough
+42 F. Ends
+83 Drive
+65 H 20'x30'
+22 Bars
+11 Cor. H.
+90 T.L. Begins
24'
25'
N. 88°30'W
Int. +28
HIGHWAY
+92 S.D.
N. 88°30'W.
Int. +70
19
13
20
17'
12'
Pole
23'
S. 87°20'E
P.L. Int. +92
18" Tile 40' long
PLATE III



Span 30'
Clear waterway 26'
Clear width 18'
Masonry abutments in very poor condition
Floor I-beam with 6" of Concrete.
12" I-beams. Guard rail cracked as shown
Bridge will need to be rebuilt. Flood water 1 ft. below bottom of floor. Foundation soil is gravel, overlaid with 3 ft. of clay. A bridge up stream 500 ft., under P.M.R.R., has 25 ft. clear waterway with 10 ft. height from surface of water to underside of floor. Roadway should not be raised to cut off floor water without providing considerable larger waterway, as tributary enters below R.R. bridge.


18"
14'
22+88 - End W. Wall
22+78 - End W. Wall
11'
18"
2'
22+71 - Cor. Abut.
22+68 - Br. Floor
6.5
6.9
2'
22+58 - Cor. Abut.
11.0
12"
12"
14'
22+40 - Cor. Abut.
2'
6.1
22+30 - Br. Floor
7.2
22+28 - Cor. Abut.
18"
34'
22+29
2'
13'
22+16
℄ Road.
Guard Rail
Sketch of Bridge
Sta. 22+30.
21+60 R.W. Begins
11.5
18"
PLATE IV

DRAINAGE.

This is claimed to be the most important part of road work. For, without a properly drained sub-base, no road metal, no matter how substantially built, can withstand the effects of the seasons. Good ditches and their outlets are very important. All information bearing on them should be absolutely complete. All culverts existing should be carefully measured and proper sketches should be made to aid the description. In culverts which are not monolithic concrete, all dimensions of the various parts, or members, should be given. The careful location of the culvert, both with respect to the centerline and the elevation, is very important. See section "Levels" for required elevations. It is just as important, if not more so, to get all information concerning culverts which are to be placed where no culvert exists at the time of the survey. When measuring up a culvert or bridge get the size of all other nearby culverts on the same stream above or below the road. Often the old culvert is far from the correct size, and a correct replacement should be made. It is often necessary to dig new outlet ditches. Run a line of levels, if necessary, to determine the possibilty and dimensions of such ditches. In the past, too little information has been obtained concerning culverts, causing much trouble in making the plans.

When looking up new drainage the law regarding natural water courses must not be overlooked. Water cannot be turned into private property unless it would naturally go there.

The direction of cross road flowage should be sketched in the transit book, as shown in the sample notes.

The following recapitulation and detailed list of things to obtain when measuring up culverts or bridges is most important and should be carefully followed:

In every case a comprehensive sketch of the bridge or culvert should be made on a separate page of the field book and the notes placed close by.

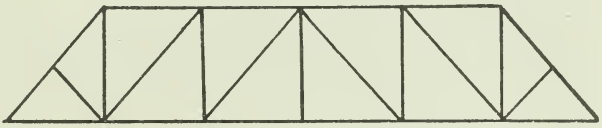
You should obtain the high and low water elevations, the clear distance between abutments, the distance from the bed of the stream to the top of the floor, and the thickness of the floor. In the case of a small culvert, or tile, do not fail to get the elevation of invert. If there are any bridges near the one in question (i. e., on the same stream) the clear distance between abutments and the height from bed of stream to underside of floor should also be obtained, as this often limits the size of bridge to be put in.

State how the center line of the bridge lies with respect to the center line of the road. The direction of flow and the angle of crossing should also be noted. The contour of the bed and at least four soundings, one at each corner, should be taken. For sounding, a $\frac{3}{4}''$ iron rod will be most useful. Give elevation of general ground where abutment will come.

Look for possible detours which will shorten the length of span or otherwise reduce the cost of erection. If the stream comes to the road and flows along side for some distance before crossing, investigate with a view to placing the bridge where the stream first comes to the road. Give the proximity and surface elevation of any nearby large lakes.

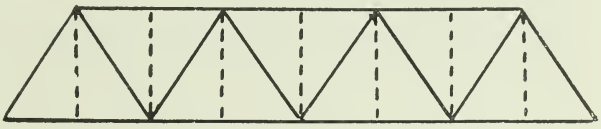
Types Of Trusses

Whipple

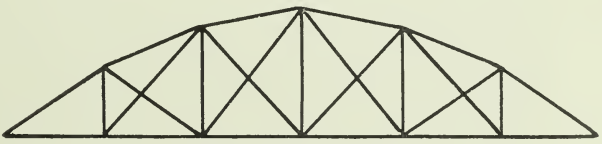


Thru Howe

Thru Pratt



Thru Warren



Bowstring

PLATE V

In measuring up steel trusses or girders always give the dimensions from center to center of pins, or center of gravity, and state which it is. The following dimensions should be obtained:

Elevations of center of pins of bottom chord.

Span.

Clear width of roadway.

Distance c. to c. of girders or trusses.

Depth of girders or truss. (Back to back of angles for girder; c. to c. of pins, or of center of gravity of section, for trusses.)

Distance from crown of road to center of gravity of bottom chord or center of pins.

Out to out distance of pedestals.

Measure accurately the thickness of all corner plates.

Give the make up of each member with all dimensions.

Give the distance from center of pins to top of masonry.

State if there are end floor beams.

If none, give elevation of masonry upon which stringers rest.

Is length out to out of girders same as distance end to end of stringers?

What are the connections between floor beams and trusses, and between stringers and floor beams?

State whether riveted or bolted.

If hangers are used give size and shape.

Are nuts on hangers upset? Size?

Show kind of kneebraces in pony trusses.

Copy all of name plate.

Give overhead clearance of roadway.

If concrete floor give thickness of concrete.

In case of concrete structures note carefully all the above data which applies, and in addition note the condition of concrete and all cracks which are not surface tracks.

Give the size, condition, style, and kind of masonry of all abutments and piers.

You may get more information than necessary, but if you omit any which is necessary, it will mean an extra trip at considerable expense.

SOIL NOTES.

These notes shall show the width, depth and character of present surfacing and the nature of the foundation material. They shall show also the general character of the country soil. Where rock is found underlying the road at a depth of three feet or less, the depth shall be determined by driving bars at stations or plusses in a sufficient number of places that a profile of the rock surface may be sketched to aid in laying grades. The character of the rock can be learned at adjacent outcroppings, or test pits may be dug. When deep cuts are necessary in a rock country, the depth of soil covering and kind of rock (as shale, limestone, trap rock, etc.) at the cut shall be determined, if the depth of soil covering is less than the proposed cut. When sink holes or bog holes are encountered the depth to solid foundation shall be determined by taking soundings at every station.

These notes shall be in a table on a separate sheet of the note book, as on Plate I.

Under "Foundation Recommendations" should be found the suggestions concerning hidden springs, under drainage, remedies for bogs, and other information needed in construction.

To facilitate the work of the office, it is important that all notes be recorded in a uniform and standard way. The loose leaf system of notekeeping enables the book for each set to be made up separately. This also necessitates extra care in getting them to the office in good shape. Tie a string through the punched holes and tie transit and level notes together before mailing. Register all notes. For Trunk Line surveys, the notes of one civil township comprise one book. For Federal Aid or Assessment District surveys the notes of each project or district comprise one book. Each book should be plainly marked for identification. Notes should be dated each day, and field party names, weather conditions, and time spent in field should be recorded. All letters and figures should be made with a 5H Eldorado or a pencil of equal grade, and should be made legibly.

Standard forms of notes shown are typical and should be carefully observed.

STANDARD SLOPE STAKE

+S	H.I.	-S	El. Ground	El. Grade	Sta.	Slope
12.50	651.0		637.5	632.9 633.0	90+00	1.0 41.9 -17.1
		1.50	638.5	T.P		
			637.5	632.9 633.0	90+00	
			635.0	630.9 631.0	89+50	2.0 26.9 -7.1
8.60	640.00		630.0	629.9 630.0	89+25	3.1 26.8 -7.0
		+0.60	631.40	T.P.		
			630.00	630.00	89+25	
12.00	632.00		622.50	628.90 629.00	89+00	3.1 16.3 ±0.0
		0.44	620.00	T.P. on	stone	
			622.50	629.00	89+00	
		8.4	612.00	627.00	88+50	3.4 27.0 +10.0
5.40	620.44	0.4	620.00	625.0	88+00	0.3 19.3 +4.9
			615.04	BM	#6.	

FORM NOTES

I	I	℄	I	I	Slope	Const.	
-6.0 3.5.0 -12.1						-18.1	
	0.0 14.0 -7.1	-2.5 0.0 -4.6			7.1 16.3 0.0	-7.1	
		-5.0 0.0 -4.0			9.0 12.0 ± 0.0	-9.1 -9.0	
	5.0 12.0 -5.1	10.0 0.0 0.0				-10.1 -10.0	
		-2.0 0.0 0.0	12.0 12.0 +10.0		13.5 29.25 +11.5	-2.0	
3.0 12.0 0.0		-9.5 0.0 +0.5				C. -3.1 F. -3.0	
		0.0 +6.5	5.4 10.0 +14.0		10.4 40.5 +19.0	+8.5	
4.4 18.0 +11.0		-8.4 0.0 +15.0	5.4 12.0 +12.0	5.4 24.0 +12.0	8.0 33.9 +14.6	+6.6	
	0.1 8.0 +4.7	-0.4 0.0 +5.0		5.0 16.0 +9.0	12.0 24.9 +16.6	+4.6	
						PLATE VI	

PLANS.

GENERAL.

Plans put out by this Department are in two standard forms: Federal Aid and Trunk Line. Federal Aid plans are of the one line profile type and will not be treated here. The standards for Trunk Line and Assessment District plans are as follows:

All sheets shall be of 10 x 10 cross section cloth, 60 inches in length. The scale of all plans shall be in 1 in. = 100 feet horizontal and 1 in. = 10 feet vertical (profile only.)

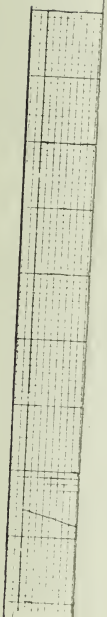
The plan shall be put acorss the top of the sheet, beginning four inches from the left hand end and extending 53 stations to the right. The center line of the right of way, shall be placed on the heavy line two inches below the top line of cross sections. Curves will be shown in the natural scale and the plan so broken as not to make confusion. At all deflections of 5° or over curves shall be shown. The curve data, △ D., R. & Ch. L. shall be put in a table conveniently near the curve. The radii at the P. C. & P. T. shall be drawn. All plus points shall be shown with plus distances. The culture shall be plotted conforming to the conventional signs on Plates VIII, IX, & X.

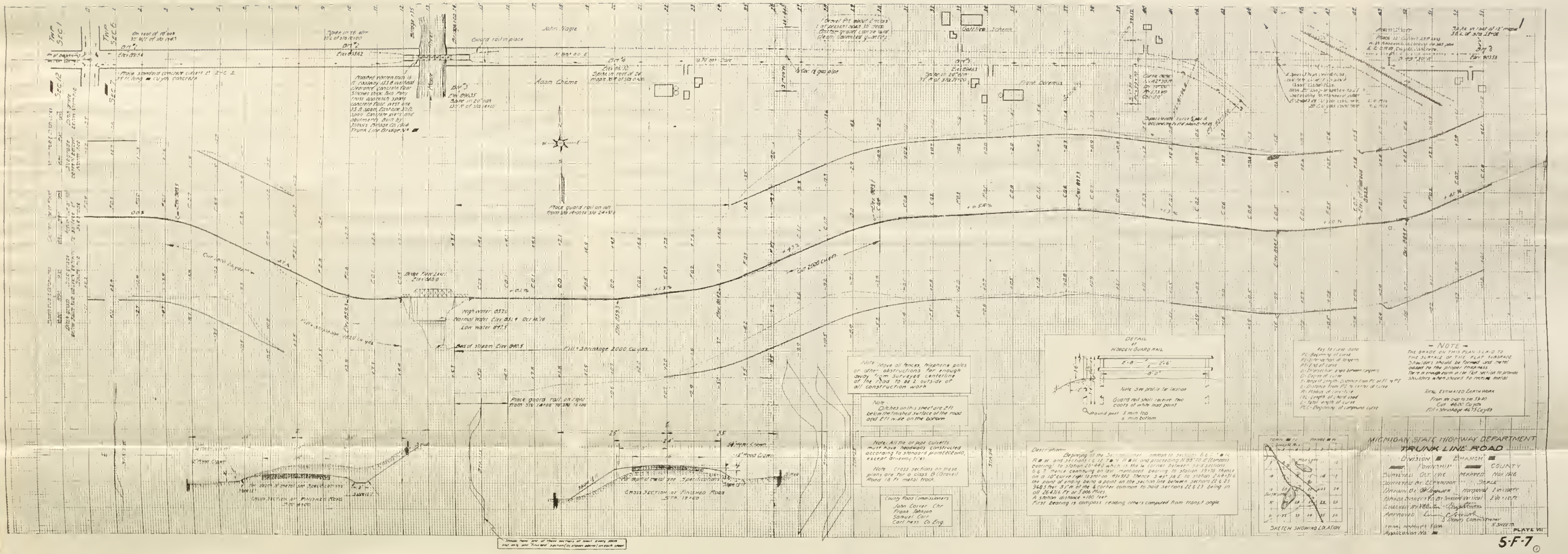
On going from one sheet to the next, the last 100 feet of the first sheet shall appear as the first 100 feet of the next sheet.

Three lines, two hubs and the center line are plotted as a profile. The left hub line shall be placed as near the plan as practicable and projected below it. The datum for the center line shall be placed three inches below that for the left hub and the datum for the right hub shall be placed three inches below that for the center line. The hub line profiles shall consist of broken dashed lines and the center line profile shall be a broken right line. The datum for the three profiles shall be labeled as shown on the left hand end of the standard plan, Plate VII. Care should be taken to get the figures for cut and fill, etc., so placed that there will be no confusion.

All plans are photographed to 3″ x 9″ in size, so all lines and figures must be clear and sharp with clean cut strokes. All loop letters and figures should be made with the loop open and clean. The size of all station numbers, cut and fill figures, etc., should not be less than 5/40 inch in height. Lower case letters in notes, etc., should be 1/10 inch high. All figures and letters should be condensed Rheinhardt or Engineering News style with 22½° slope. A so-called "fat" letter must be avoided. The general form and lay out of the standard plan should be followed in all cases.

The title on the first sheet of a set of plans shall be a copy of the one shown on standard plan and shall be placed in the lower right hand corner of the sheet and shall be spaced and located as shown. The following sheets shall bear a small title spaced similar to the one on standard plan.




Note - Move all fences, telephone poles or other obstructions far enough away from surveyed centerline of the road to be 2 outside of all construction work
Note. Ditches on this sheet are 2 ft below the finished surface of the road and 2 ft wide on the bottom
Note: All tile or pipe culverts must have headwalls constructed according to standard plans E&C 2 or 10, except driveway tiles
Note Cross sections on these plans are for a class B (Gravel) Road 16 ft metal track.
County Road Commissioners
John Carver Chr
Frank Johnson
Samuel Carr
Carl Hess Co. Eng.
DETAIL of WOODEN GUARD RAIL
Note See profile for location
Guard rail shall receive two coats of white lead paint
Round post 5 min top 6 min bottom
Description
A station distance = 100 feet
First bearing is compass reading others computed from transit angle.
Key to curve data
PC - Beginning of curve
PI - Intersection of tangents
PT - End of curve
Δ - Intersection angle between tangents
D - Degree of curve
T - Tangent length - Distance from PC or PT to PI
E - Distance from PI to center of curve
R - Radius of curvature
CHL - Length of chord used
L - Total length of curve
PCC - Beginning of compound curve
- NOTE -
THE GRADE ON THIS PLAN IS LAID TO THE SURFACE OF THE FLAT SUBGRADE
Shoulders should be formed and metal added to the proper thickness
There is enough earth in the flat section to provide shoulders when shaped to receive metal
Total Estimated Earth Work
Cut 4600 Cu yds
Fill + Shrinkage 4675 Cu yds
Fill + Shrinkage 2000 Cu yds
Cut 2000 Cu yds
Place guard rail on left
Place guard rail on right
Cross Section of Finished Road
SKETCH SHOWING LOCATION
MICHIGAN STATE HIGHWAY DEPARTMENT
TRUNK LINE ROAD
DIVISION [redacted] BRANCH [redacted]
[redacted] TOWNSHIP [redacted] COUNTY
Surveyed Oct. 1916 Mapped Nov. 1916
Scale
Horizontal 1 in = 100 ft
Vertical 1 in = 10 ft
Approved
Deputy Commissioner
5 SHEETS
Application No. [redacted]
PLATE VII

5·F·7

Conventional Signs.

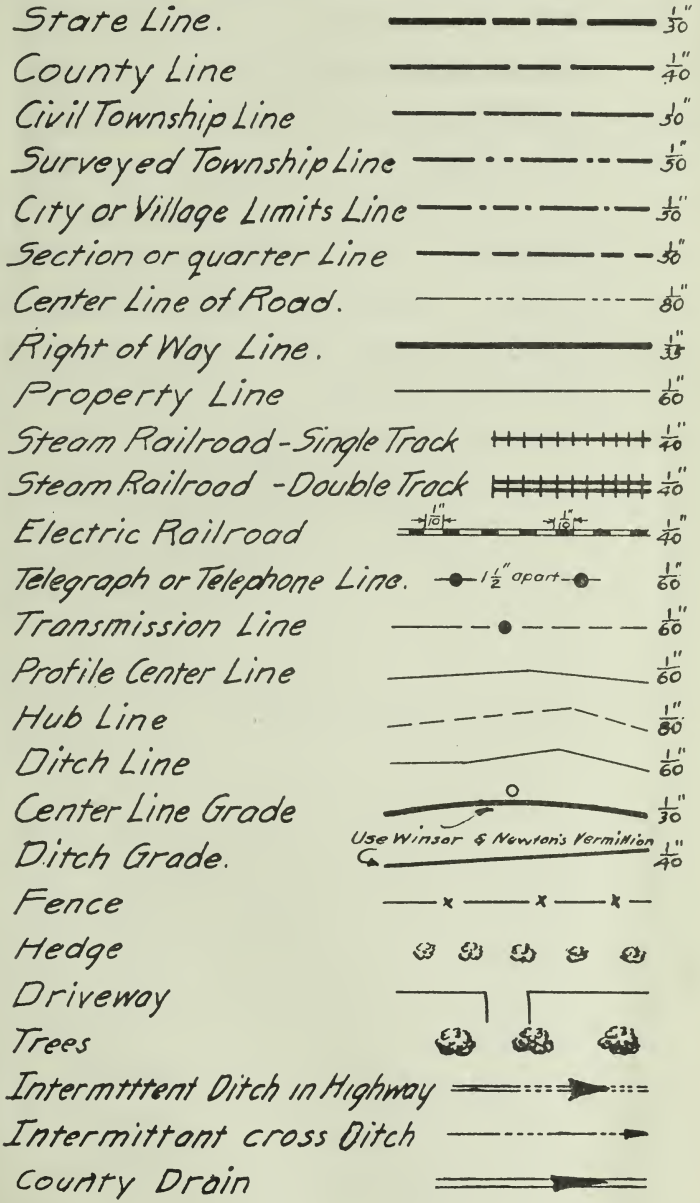


PLATE VIII

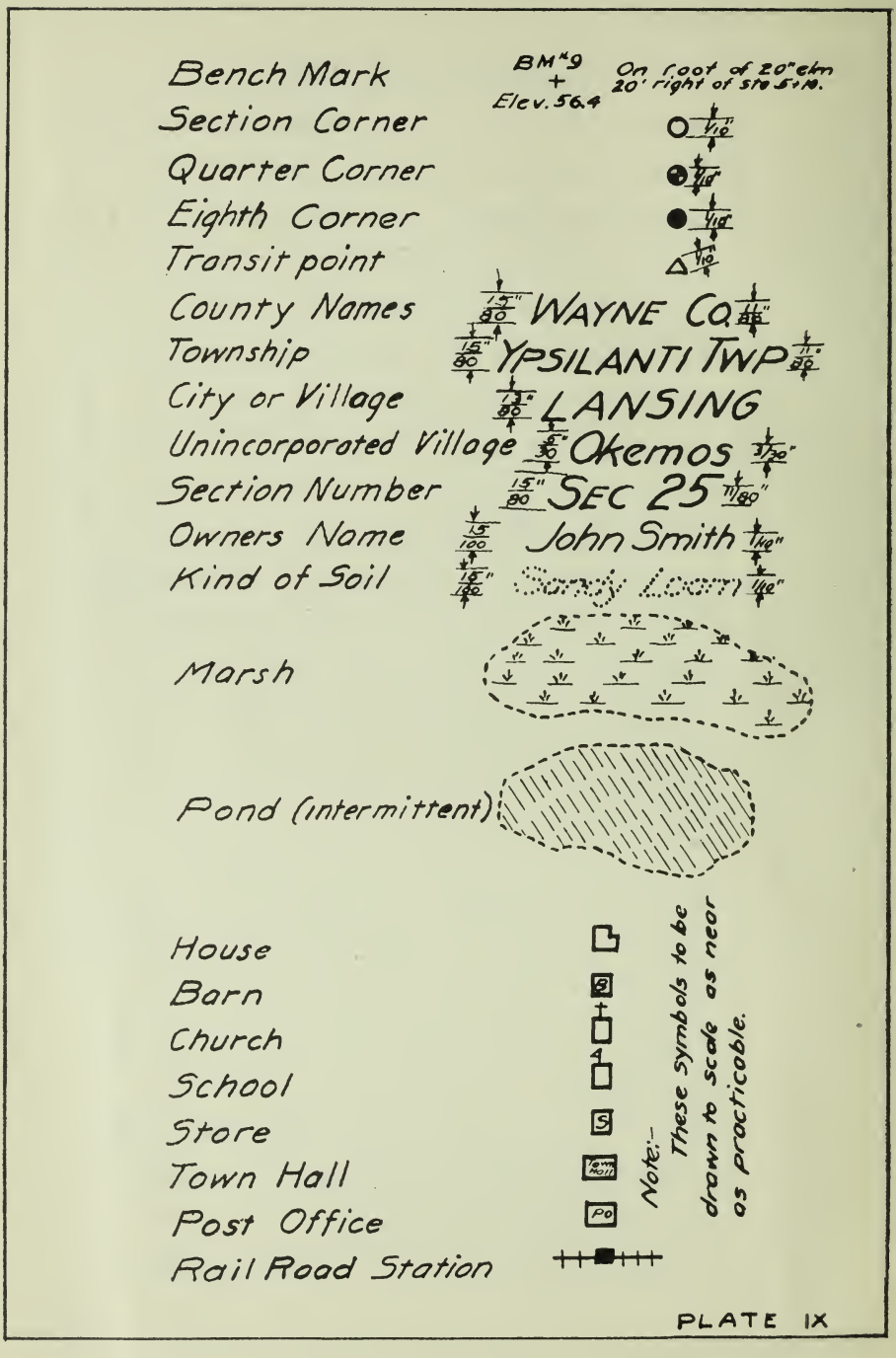
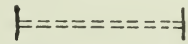

Bench Mark
BM #9
+
Elev. 564
On root of 20" elm
20' right of sta 5+10.
Section Corner
Quarter Corner
Eighth Corner
Transit point
County Names
WAYNE CO.
Township
YPSILANTI TWP
City or Village
LANSING
Unincorporated Village
Okemos
Section Number
SEC 25
Owners Name
John Smith
Kind of Soil
Sandy Loam
Marsh
Pond (intermittent)
House
Barn
Church
School
Store
Town Hall
Post Office
Rail Road Station
Town Hall
Po
Note:-
These symbols to be drawn to scale as near as practicable.

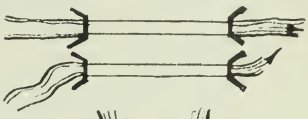
PLATE IX

Cemetery 

Tile or pipe

Some with headwall 

Slob Culvert

Arch Culvert 

Two span arch bridge

Steel bridge - Single span

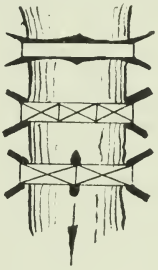
Steel bridge - Two span 

PLATE X

A meridian arrow shall be placed on each sheet and follow the standard.

The sheet number shall appear in the upper right hand corner of the sheet and shall conform to the standard as shown on blue print which the Department furnishes. Care should be taken that on plans bearing the same file number the sheet numbers are not duplicated.

All bench marks shall be shown on plans as near the actual location as possible and the description shall be placed at a convenient place with an arrow pointing to the bench mark to which it refers.

One cross section showing the finished shape of the road shall appear on each sheet. These sections should be alternate cut and fill sections. Plates XI, XII, XIII, XIV, XV, and XVI inclusive, illustrate these sections and give the dimensions for the various kinds and widths of metal. The sections from which the earth work is figured should be platted along the bottom of the sheet. The right hub should be placed nearest the bottom of the sheet and the top of the section should be toward the left hand. On completing the sheet about every fifth one should be inked unless the ground is very irregular when a sufficient number should be inked to show the nature of the ground. See Plate XVII for detail and also see section "Laying Grades."

All curves whose radii are less than 700 feet are to be super-elevated in accordance with standard plan E-4-A-29, except those curves at road intersections which are not to be super-elevated.

Where there is a fill of six feet or over, figuring from the hub elevation, a guard rail shall be placed and it should extend beyond the six foot fill to a point near where the fill runs out. The guard rail detail as shown on Plate XVIII should appear once on each set of plans which call for a guard rail. A cross section showing guard rail should be shown as on Plate XIX. The extent of the guard rail should be shown on the plans near the hub line profile on the side on which the guard rail is to be placed. See Standard Profile.

An engineer's description shall appear on the title sheet of each set of plans and should conform to that shown on the standard plan.

The following notes should appear on each set of plans and should all be put on the title sheet except the one giving earthwork which should be put on each sheet and give the earthwork for that sheet only.

1. "Cross sections on these plans are for Class E (Macadam Road) 16 feet metal track." This note should be changed to fit each case.

2. *"The grade on this plan is laid to the surface of the flat subgrade.* Shoulders should be formed and metal added to the proper thickness. There is enough earth in the flat section to provide shoulders when shaped to receive the metal."

3. "Move all fences, telephone poles or other obstructions far enough away from the surveyed center line to be two feet outside of all construction work."

4. A list of County Road Commissioners or Township Highway Officials shoud be put on the title sheet of each set of plans.

5.

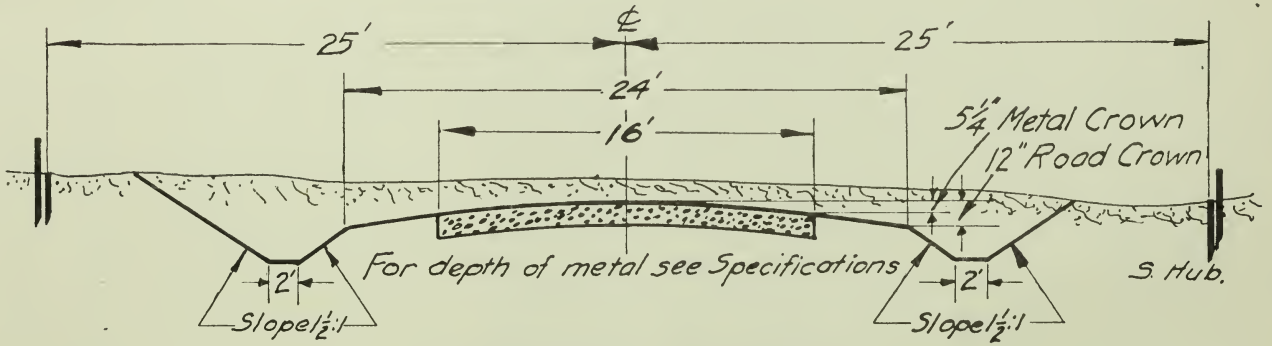
Total Estimated Earthwork
From Sta..... to Sta.....
Cut.....cu. yds.
Fill + Shrinkage.... cu. yds.

6. Ditches from Sta. 53 to 79 are 24″ below center of finished road. From 79 to 104 they are independent of center line grade. All ditches are 24″ wide on the bottom. (This note should be changed to fit each sheet.)

The most satisfactory method of working up road plans has been found to be to make the plan with a temporary grade, blue print it, and inspect it in the field for grade, drainage and culvert structures. The print is returned to the office and the plan is finished according to the advice thereon.

When beginning a set of plans, first ink in titles and file and sheet numbers. Then detail and ink the transit line and topography. Ink in whatever notes relate to present culvert structures and pencil in recommendation for future culvert structures. In case a bridge of 30 feet span or over is found on trunk line, report it to the Bridge Department and get from them a number for it. This number should be put on the plans together with "This bridge is not a part of these plans" and is all that need be said about future work on the structure. In case such a structure is not on trunk line, the advice number should be obtained and put on the plans.

The next operation is platting the profiles. The datum line of the left hub should be chosen so that the hub line will not interfere with the plan and so that the right hub will not run off the sheet. The profile should not be broken if possible to get it on the sheet without. After the three profiles are plotted in ink the sections of the original ground surface should be put at the bottom of the sheet in pencil. The plan is now ready to lay grade.



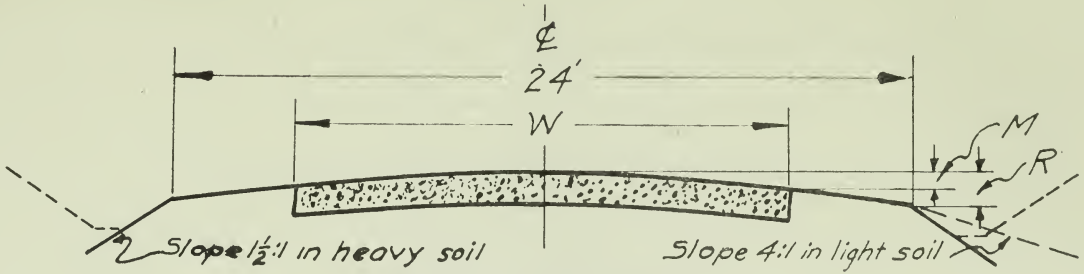
CROSS SECTION STA 5+00

For other widths and classes of metal see Plates 12, 13, 14, 15 & 16.

STANDARD CROSS SECTIONS FOR CLASS A, B, C- ROADS
16 ft Metal.

On plans this section shall be drawn to a scale 1 in = 6 ft.
All Road Crown Sections shall conform to this

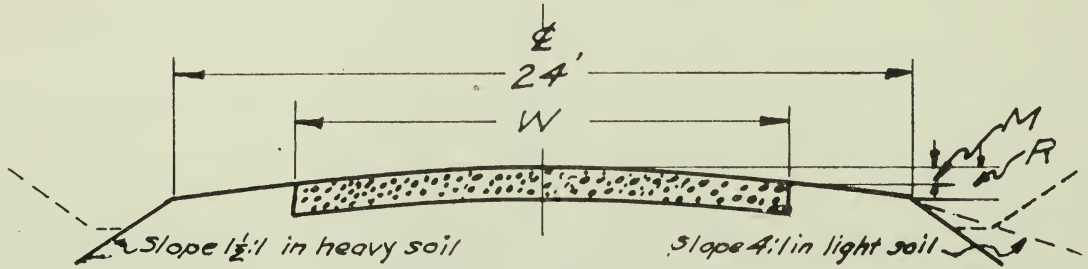
PLATE XI



Road and Metal Crowns for different Widths of Metal		
W	M	R
16'	5¼"	12"
15'	4¾"	12"
14'	4½"	12"
12'	4"	12"
11		
10'	3½"	12"
9'	3"	12"

STANDARD ROAD CROWN CLASS A-B-C-ROADS.

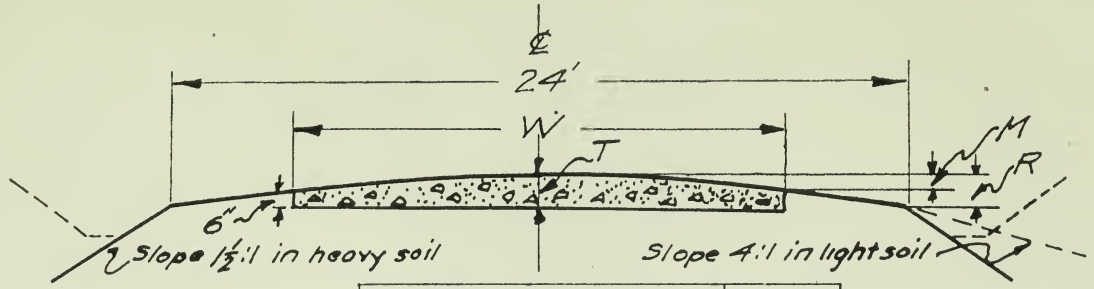
PLATE XII



Road and Metal Crown for different Widths of Metal		
W	M	R
16'	5"	9"
15'	4½"	9"
14'	4"	9"
12'	3"	9"
10'	2½"	9"
9'	2½"	9"

STANDARD ROAD CROWN - CLASS D-E ROADS.

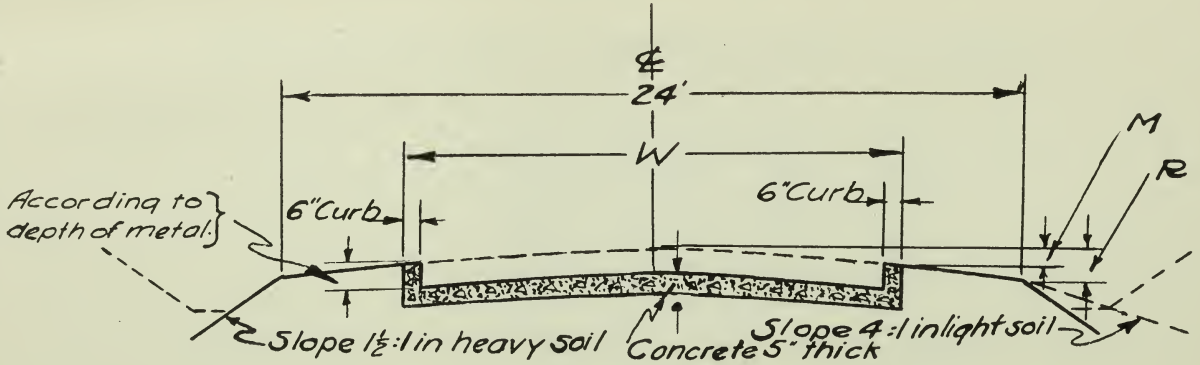
PLATE XIII



Road and Metal Crown for different Widths of Metal			Thickness of metal at ℄ of Road
W	M	R	T
20'	2½"	3"	8½"
18'	2¼"	3"	8¼"
16'	2"	4"	8"
15'	1¾	5"	7¾
14'	1¾	5"	7¾
12'	1½	6"	7½"

STANDARD ROAD CROWN - CLASS F ROAD.

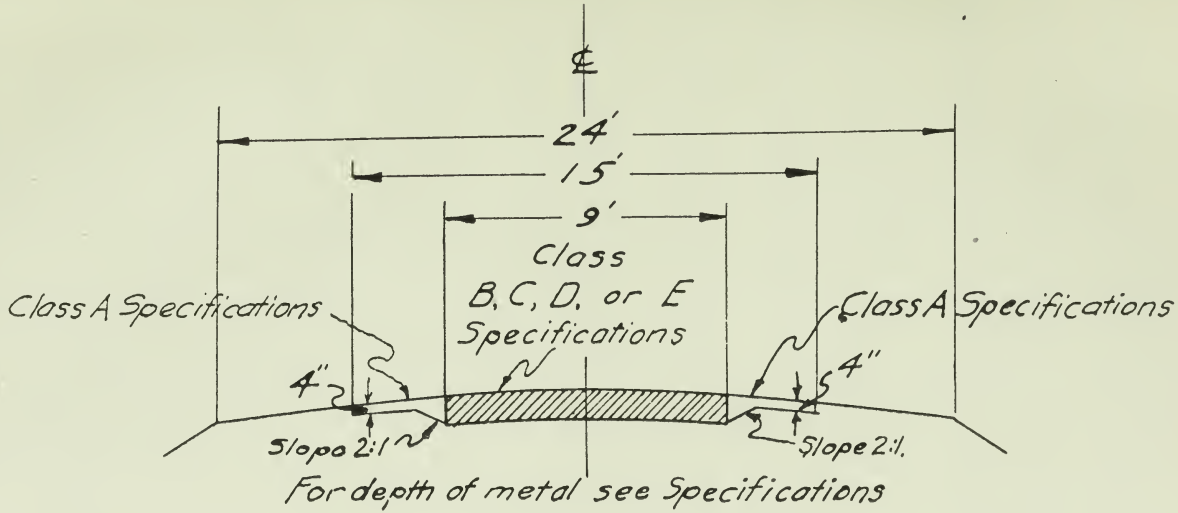
PLATE XIV



Road and Metal Crowns for different Widths of Metal		
W	M	R
20'	2½"	8½"
18'	2¼"	8¼"
16'	2 "	8 "
15'	1¾"	7¾"
14'	1¾"	7¾"
12'	1½"	7 "

STANDARD ROAD CROWN Concrete Base.

PLATE XV



STANDARD ROAD CROWN
CLASS B, C, D, E, ROADS
WITH CLASS A SHOULDER.

PLATE XVI

LAYING GRADES.

Before starting to lay grade the following items should be carefully considered:

1. The importance of the road. A side road does not, in general, require so much grading as one on a main line.

2. Its location in the state. A road south of a line from Muskegon to Bay City will, in general, demand a smaller maximum grade than one north of that line.

3. Kind of soil. The size of the ditch and the amount which the whole grade is turnpiked is determined by the porosity of the soil, the object being to secure a dry sub-base for the metal.

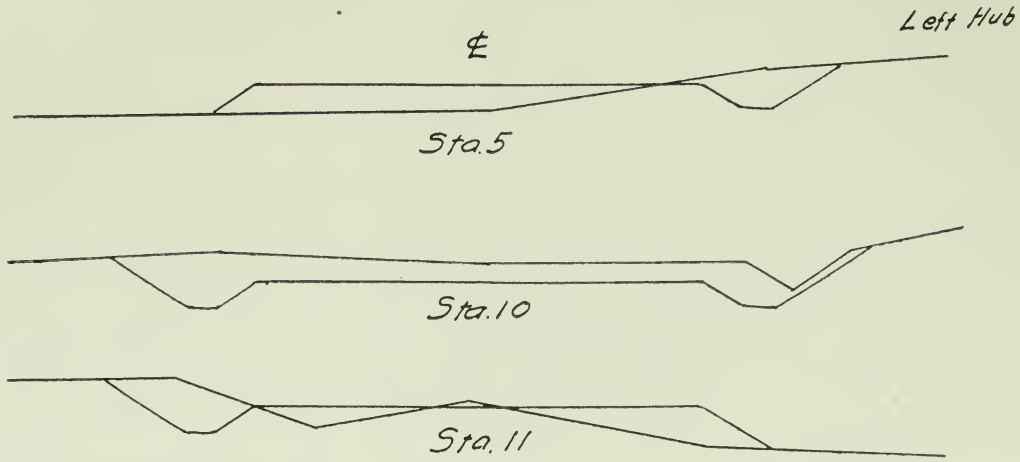
4. Drainage. The present conditions of the drainage of the road and the surrounding terrain controls, to a certain extent, the new grade of the center line and of the ditches.

5. The kind and condition of the present road bed. For resurfacing work only smoothing up is required. It is desirable to disturb a hard roadbed as little as possible.

6. Damage which large cuts or fills may do to abutting property. Large cuts or fills should not be made at cross roads until careful consideration has shown that to be the best thing to do.

7. When a long hill is encountered one should be careful to avoid the use of adverse grades if possible to do so.

As seen in Note 2 on Page 32, the earthwork is figured to a flat top section 0.6 ft. below the finished surface of the road. This section is normally 24 ft. in width in cut and fill. Often it is desirable to narrow the grade in cut in the northern part of the lower peninsula to 22 ft. or 20 ft. in width to avoid excessive earthwork. In no case, however, is the grade of a fill to be less than 24 ft. in width. The maximum grade of a road is determined by the State Highway Commissioner for Class A and B roads. For Classes C, D, E, F & G, a maximum grade of 6 per cent is established by the Highway Law. It is desirable to have low rates of grade in the more thickly settled portions of the state. Four per cent should not be exceeded if the conditions will allow it. Once the maximum grade of a road is established it determines the largest load which can be hauled over it and it is unwise to make excessive cuts to secure lower grades. Long shallow cuts should be avoided as they are expensive and are seldom worth the cost. The length of haul should not exceed 500 ft. whenever possible to avoid it. Changes in the rate of grade of 2% or over require a vertical easement curve. As a rule these curves should not be less than 200 ft. in length. As far as practicable rates of grade should be established at even tenths of per cent. This makes the work of computing easier. The middle correction for easement curves may be figured by the following formula: $\frac{G_2 - G_1}{8} \times \frac{\text{length}}{100}$, G_1 & G_2 being the rates of grade which intersect. Intermediate corrections vary as the square of their distance from the



Sections plotted to subgrade should be inked after volumes have been computed.

PLATE XVII

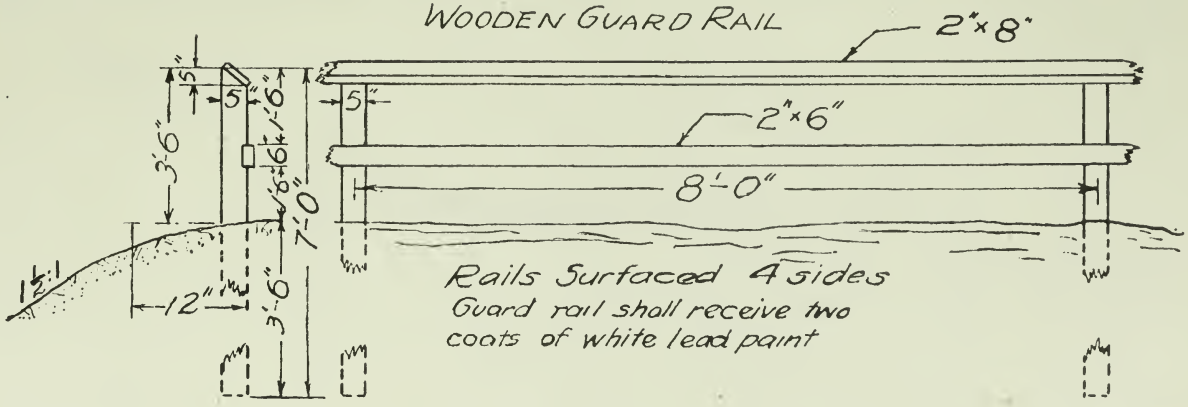
nearest end of the curve. Short choppy grades must be avoided. Ditches should, in general, have a grade parallel to the road grade. It is desirable to have ditch grades 0.4% or more. The minimum grade allowed is 0.1%.

The best method to attack the problem of laying grades is to stretch the string from hill top to valley to hill top in a rough grade estimating a balance as closely as possible, using long grades. The grade is gone over a second time adjusting more carefully for per cent of grade and balance by breaking up the long grades. While adjusting the grade it is a good plan to try the areas of the sections with the template without plotting, estimating cut against fill by the eye. Much time can be saved by so doing. This method of adjusting is continued until one is satisfied that the grade balances (allowing for a fill shrinkage of 10% to 30%), and that the foregoing conditions have been fulfilled. The grade string is left pinned to the sheet and the sections of the sub-grade are penciled with a template over the original ground sections. The cut or fill shown is planimetered and the cubic yardage obtained from tables. Care should be used to plot accurately with the template. The ditches must be observed closely so that independent ditches are not overlooked and plotted wrong. If the volumes do not balance the grade must be changed until they do. Considerable time may be saved in doing this, if the amount of the proposed change is roughly figured with a slide rule. The final sections should be planimetered and the total estimate revised. Blanks are furnished for the figures for the grade and for volumes. After the volumes are adjusted, the elevation of breaks in grade, the center line cuts and fills, and the amounts of yardage for the various sections are penciled in with a soft black pencil. The center line grade line and ditch grade lines and the future culvert recommendations are also penciled in. The location sketch is put on and the sheet is handed to the checker.

After grade inspection in the field the plan is ready to complete. The advice given on the blue prints should be carefully considered. Alterations in the grade that are necessary should be made, and the volumes refigured. The final volumes should be set down on the right-hand end of the sheet as shown on Standard Plan. The figures referencing the grade to the hubs, the ditch cuts, and the center line cuts and fills should be inked in as shown on the standard plan.

The new culvert structures should be specified after the manner of the standard plan. For new work, culverts, 12″ to 18″ diameter, specify either corrugated metal, cast iron, or tile encased in 3″ of 1:2:4 concrete, according to standard plans E-2-C-2, and E-2-C-10. The minimum length of a culvert of a cross road is 35 ft. and should be built with a curved head wall. Where there is not at least one foot of earth cover for the circular culverts substitute the reinforced concrete box culvert E-2-C-11. For culverts requiring more area of waterway than that given by the 18″ circular type, reinforced concrete culverts must be specified. For culverts requiring spans of 3′ to 15′ clear with only the metal fill on the floor of the culvert specify E-2-C-13. This culvert is designed for only one length 25′ - 6″ and no attempt should be made to lengthen it. Where the size of culvert called for gives an earth fill to sub-grade of two ft. or less the height of the grade may be altered or the size of culvert may

DETAIL
of
WOODEN GUARD RAIL

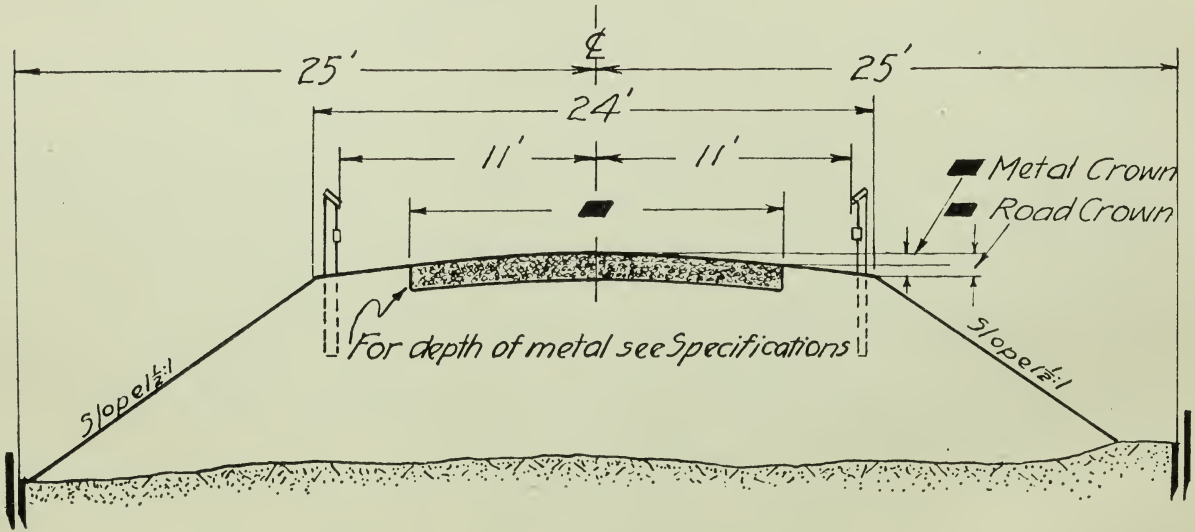


5" Round post
5" Top minimum
6" bottom min.

Note See profile for location.

STANDARD GUARD RAIL.

PLATE XVIII



STANDARD CROSS SECTION
SHOWING
GUARD RAIL

PLATE XIX

be increased so that the final sub-grade fill does not exceed one foot. If this cannot be done culvert E-2-C-14 must be substituted. Its length is arrived at by adding to the minimum length of 25′ - 6″ *three* feet for each *one* foot of earth fill on the floor more than the first 0.5 ft. E-2-C-14 is designed for spans up to and including 9.0 ft. For spans up to 20.0 the arches A-1-B-1, A-1-B-2, A-1-B-3, A-1-B-4, and A-1-B-5 are to be specified under fills. For clear spans from 15.0′ to 29.0′ where no fill is found, Standard I-Beam, T-Beam, or concrete Girders are to be specified. At present, owing to difficulty of obtaining I-Beams, it is better not to specify them.

Repairing old culverts is desirable when the old culverts are in condition to warrant it. For this work, special designs are required in most cases. Do not attempt to extend or repair an old I-Beam or slab culvert without first ascertaining if it is strong enough to sustain an 18 ton moving road roller.

All notes, descriptions, sections, etc., should now be put on the plan and the sheets handed to the checker. When he returns the plans, make the corrections noted by him and then, (not before) ink in the grade lines using Winsor & Newton's Vermillion. The plan should now be complete and should be handed to the Chief Draftsman. All sheets of computations should be filed in their proper place. All time should be carefully kept on the blanks provided.

EXPLANATION OF TABLES.

The usual nomenclature for curve data is used in these tables.

Table I. The radius and tangent are both computed by logarithms for every change of ten minutes in deflection, from a total deflection of 5° 00′ to one of 100° 00′. The radius is computed from the equation $R = \frac{E}{E \text{ Sec. } \frac{1}{2} \triangle}$, in which an external distance of one foot is used. The value of R, thus secured, is substituted in the formula $T = R \tan \frac{1}{2} \triangle$ in order to get the corresponding length of tangent. To find R and T for other values of E, multiply given quantities by new value of E.

Table II. These subchord deflections are computed from the formula $\sin \frac{1}{2} d = \frac{c}{2R}$ (see Allen: Railroad Curves and Earthwork, Fourth Edition, page 24, Article 49.) for certain subchords specified on page 11 of these Instructions. All computations were made by logarithms. The approximate formulas cannot be expected to check closely on very sharp curves.

LENGTH OF CURVE. It is obviously incorrect to expect the length of a circular arc to equal the sum of a series of straight chords, altho, that would be sufficiently correct for long, easy curves. For sharp curves, however, the following formula should be used:

$$L = \frac{\frac{1}{2} \triangle \text{ (in minutes)}}{\frac{1}{2} d \text{ (in minutes)}} \times \text{length of subchord.}$$

TYPICAL EXAMPLE.

$\triangle = 70° 40'$ (measured)
$E = 20$ (assumed)
From Table 1
$R = 4.429 \times 20 = 88.580$ ft.
From Table 2 nearest R = 88.65 ft.
$88.65 \div 4.429 = 20.02$
$\triangle = 70° 40'$
$E = 20.02$
$R = 88.65$
From Table 1
$T = 3.140 \times 20.02 = 62.863$
$L = \frac{35° 20'}{3° 13'.99} \times 10 = \frac{21200}{193.99} = 109.284$

$\frac{1}{2} \triangle = 35° 20'$
From Table 2
$D = 68° 40'$
$\frac{1}{2} d = 3° 13'.99$

P. I. =	204 + 32.9
T =	62.863
P. C. =	203 + 70.037
L =	1 + 09.284
P. T. =	204 + 79.321

Station	Plate Reading
P. C. = 203 + 70	0° 00′.00
+ 80	3° 13′.99
+ 90	6° 27′.98
204 + 00	9° 41′.97
+ 10	12° 55′.96
+ 20	16° 09′.96
+ 30	19° 23′.94
+ 40	22° 37′.93
+ 50	25° 51′.92
+ 60	29° 05′.91
+ 70	32° 19′.90
P. T. = 204 + 79.3	35° 20′.00

TABLE I.

Δ	R	T	Δ	R	T	Δ	R	T
3° 0′	2917.22	76.39	13° 0′	154.57	17.61	23° 0′	48.812	9.931
10′	2618.13	72.37	10′	150.66	17.39	10′	48.101	9.859
20′	2362.79	68.75	20′	146.89	17.17	20′	47.404	9.788
30′	2144.02	65.51	30′	143.27	16.96	30′	46.722	9.718
40′	1952.57	62.50	40′	139.77	16.75	40′	46.055	9.649
50′	1786.40	59.78	50′	136.41	16.55	50′	45.401	9.581
4° 0′	1640.57	57.29	14° 0′	133.16	16.350	24° 0′	44.762	9.514
10′	1511.88	55.00	10′	130.02	16.157	10′	44.135	9.448
20′	1397.76	52.88	20′	127.00	15.969	20′	43.521	9.383
30′	1296.08	50.92	30′	124.05	15.785	30′	42.921	9.319
40′	1205.09	49.10	40′	121.25	15.605	40′	42.330	9.255
50′	1123.36	47.41	50′	118.53	15.429	50′	41.753	9.193
5° 0′	1049.67	45.83	15° 0′	115.99	15.257	25° 0′	40.998	9.089
10′	982.98	44.35	10′	113.34	15.089	10′	40.632	9.070
20′	922.46	42.96	20′	110.87	14.924	20′	40.088	9.010
30′	867.35	41.66	30′	108.48	14.764	30′	39.555	8.950
40′	817.03	40.44	40′	106.14	14.606	40′	39.032	8.892
50′	770.96	39.28	50′	103.93	14.452	50′	38.520	8.834
6° 0′	728.68	38.19	16° 0′	101.75	14.301	26° 0′	38.017	8.777
10′	689.78	37.16	10′	99.650	14.153	10′	37.524	8.721
20′	653.91	36.18	20′	97.610	14.008	20′	37.040	8.665
30′	620.76	35.25	30′	95.631	13.863	30′	36.565	8.610
40′	590.07	34.37	40′	93.712	13.727	40′	36.099	8.555
50′	561.60	33.53	50′	91.849	13.590	50′	35.641	8.502
7° 0′	535.14	32.73	17° 0′	90.040	13.456	27° 0′	35.192	8.449
10′	510.50	31.97	10′	88.284	13.325	10′	34.752	8.397
20′	487.52	31.24	20′	86.579	13.197	20′	34.319	8.345
30′	466.05	30.54	30′	84.922	13.071	30′	33.894	8.294
40′	445.98	29.88	40′	83.312	12.947	40′	33.477	8.243
50′	427.17	29.25	50′	81.740	12.825	50′	33.067	8.194
8° 0′	409.52	28.64	18° 0′	80.224	12.706	28° 0′	32.665	8.144
10′	392.94	28.05	10′	78.743	12.589	10′	32.270	8.096
20′	377.35	27.49	20′	77.301	12.474	20′	31.882	8.048
30′	362.66	26.95	30′	75.902	12.361	30′	31.500	8.000
40′	348.83	26.43	40′	74.537	12.250	40′	31.125	7.953
50′	335.74	25.93	50′	73.210	12.142	50′	30.757	7.907
9° 0′	223.40	25.45	19° 0′	71.916	12.035	29° 0′	30.405	7.861
10′	312.71	24.99	10′	70.656	11.929	10′	30.039	7.815
20′	300.65	24.54	20′	69.429	11.826	20′	29.689	7.770
30′	290.16	24.11	30′	68.233	11.725	30′	29.345	7.726
40′	280.22	23.69	40′	67.068	11.625	40′	29.007	7.682
50′	270.77	23.29	50′	65.931	11.527	50′	28.675	7.639
10° 0′	261.79	22.90	20° 0′	64.823	11.430	30° 0′	28.348	7.596
10′	253.25	22.53	10′	63.742	11.335	10′	28.026	7.553
20′	245.12	22.16	20′	62.688	11.242	20′	27.710	7.511
30′	237.38	21.81	30′	61.659	11.150	30′	27.399	7.470
40′	229.99	21.47	40′	60.656	11.059	40′	27.093	7.429
50′	222.94	21.14	50′	59.676	10.970	50′	26.792	7.388
11° 0′	216.21	20.82	21° 0′	58.719	10.883	31° 0′	26.496	7.348
10′	209.78	20.51	10′	57.785	10.797	10′	26.204	7.308
20′	203.64	20.21	20′	56.873	10.712	20′	25.917	7.269
30′	197.75	19.91	30′	55.981	10.628	30′	25.635	7.230
40′	192.12	19.63	40′	55.111	10.546	40′	25.357	7.191
50′	186.72	19.35	50′	54.259	10.465	50′	25.083	7.153
12° 0′	181.54	19.08	22° 0′	53.428	10.385	32° 0′	24.814	7.115
10′	176.58	18.82	10′	52.615	10.307	10′	24.551	7.078
20′	171.83	18.57	20′	51.821	10.230	20′	24.288	7.041
30′	167.25	18.32	30′	51.043	10.153	30′	24.031	7.004
40′	162.85	18.08	40′	50.283	10.078	40′	23.778	6.968
50′	158.63	17.84	50′	49.540	10.004	50′	23.529	6.932

EXPLANATION OF TABLES.

[illegible] for curve data is used in these tables.

[illegible]

$T = 3.140 \times 26' = 81.64$ $\frac{1}{2}$ d = 2° 29′.4

$L = \frac{35° 20'}{2° 29'.4} \times 10 = \frac{2120}{149.4} \times 10$

Log 21200 = 4.326336
Log 149.4 = 2.174351
Log L = 2.151985
Log L = 141.9

P. I. = 204 + 21.5
T = 81.6
P. C. = 203 + 39.9
L = 1 + 41.9
P. T. = 204 + 81.8

Station	Plate Reading
P. C.=203 + 39.9	0° 00′.0
203 + 50	2° 29 .4
+ 60	4° 58 .8
+ 70	7° 28 .2
+ 80	9° 57 .6
+ 90	12° 27 .0
204 + 00	14° 56 .4
+ 10	17° 25 .8
+ 20	19° 55 .2
+ 30	22° 24 .6
+ 40	24° 54 .0
+ 50	27° 23 .4
+ 60	29° 52 .8
+ 70	32° 22 .2
+ 80	24° 51 .6
P. T.=204 + 81.8	25° 18 .5

TABLE I.

Δ	R	T	Δ	R	T	Δ	R	T
3° 0′	2917.22	76.39	13° 0′	154.57	17.61	23° 0′	48.812	9.931
10′	2618.13	72.37	10′	150.66	17.39	10′	48.101	9.859
20′	2362.79	68.75	20′	146.89	17.17	20′	47.404	9.788
30′	2144.02	65.51	30′	143.27	16.96	30′	46.722	9.718
40′	1952.57	62.50	40′	139.77	16.75	40′	46.055	9.649
50′	1786.40	59.78	50′	136.41	16.55	50′	45.401	9.581
4° 0′	1640.57	57.29	14° 0′	133.16	16.350	24° 0′	44.762	9.514
10′	1511.88	55.00	10′	130.02	16.157	10′	44.135	9.448
20′	1397.76	52.88	20′	127.00	15.969	20′	43.521	9.383
30′	1296.08	50.92	30′	124.05	15.785	30′	42.921	9.319
40′	1205.09	49.10	40′	121.25	15.605	40′	42.330	9.255
50′	1123.36	47.41	50′	118.53	15.429	50′	41.753	9.193
5° 0′	1049.67	45.83	15° 0′	115.99	15.257	25° 0′	40.998	9.089
10′	982.98	44.35	10′	113.34	15.089	10′	40.632	9.070
20′	922.46	42.96	20′	110.87	14.924	20′	40.088	9.010
30′	867.35	41.66	30′	108.48	14.764	30′	39.555	8.950
40′	817.03	40.44	40′	106.14	14.606	40′	39.032	8.892
50′	770.96	39.28	50′	103.93	14.452	50′	38.520	8.834
6° 0′	728.68	38.19	16° 0′	101.75	14.301	26° 0′	38.017	8.777
10′	689.78	37.16	10′	99.650	14.153	10′	37.524	8.721
20′	653.91	36.18	20′	97.610	14.008	20′	37.040	8.665
30′	620.76	35.25	30′	95.631	13.863	30′	36.565	8.610
40′	590.07	34.37	40′	93.712	13.727	40′	36.099	8.555
50′	561.60	33.53	50′	91.849	13.590	50′	35.641	8.502
7° 0′	535.14	32.73	17° 0′	90.040	13.456	27° 0′	35.192	8.449
10′	510.50	31.97	10′	88.284	13.325	10′	34.752	8.397
20′	487.52	31.24	20′	86.579	13.197	20′	34.319	8.345
30′	466.05	30.54	30′	84.922	13.071	30′	33.894	8.294
40′	445.98	29.88	40′	83.312	12.947	40′	33.477	8.243
50′	427.17	29.25	50′	81.740	12.825	50′	33.067	8.194
8° 0′	409.52	28.64	18° 0′	80.224	12.706	28° 0′	32.665	8.144
10′	392.94	28.05	10′	78.743	12.589	10′	32.270	8.096
20′	377.35	27.49	20′	77.301	12.474	20′	31.882	8.048
30′	362.66	26.95	30′	75.902	12.361	30′	31.500	8.000
40′	348.83	26.43	40′	74.537	12.250	40′	31.125	7.953
50′	335.74	25.93	50′	73.210	12.142	50′	30.757	7.907
9° 0′	223.40	25.45	19° 0′	71.916	12.035	29° 0′	30.405	7.861
10′	312.71	24.99	10′	70.656	11.929	10′	30.039	7.815
20′	300.65	24.54	20′	69.429	11.826	20′	29.689	7.770
30′	290.16	24.11	30′	68.233	11.725	30′	29.345	7.726
40′	280.22	23.69	40′	67.068	11.625	40′	29.007	7.682
50′	270.77	23.29	50′	65.931	11.527	50′	28.675	7.639
10° 0′	261.79	22.90	20° 0′	64.823	11.430	30° 0′	28.348	7.596
10′	253.25	22.53	10′	63.742	11.335	10′	28.026	7.553
20′	245.12	22.16	20′	62.688	11.242	20′	27.710	7.511
30′	237.38	21.81	30′	61.659	11.150	30′	27.399	7.470
40′	229.99	21.47	40′	60.656	11.059	40′	27.093	7.429
50′	222.94	21.14	50′	59.676	10.970	50′	26.792	7.388
11° 0′	216.21	20.82	21° 0′	58.719	10.883	31° 0′	26.496	7.348
10′	209.78	20.51	10′	57.785	10.797	10′	26.204	7.308
20′	203.64	20.21	20′	56.873	10.712	20′	25.917	7.269
30′	197.75	19.91	30′	55.981	10.628	30′	25.635	7.230
40′	192.12	19.63	40′	55.111	10.546	40′	25.357	7.191
50′	186.72	19.35	50′	54.259	10.465	50′	25.083	7.153
12° 0′	181.54	19.08	22° 0′	53.428	10.385	32° 0′	24.814	7.115
10′	176.58	18.82	10′	52.615	10.307	10′	24.551	7.078
20′	171.83	18.57	20′	51.821	10.230	20′	24.288	7.041
30′	167.25	18.32	30′	51.043	10.153	30′	24.031	7.004
40′	162.85	18.08	40′	50.283	10.078	40′	23.778	6.968
50′	158.63	17.84	50′	49.540	10.004	50′	23.529	6.932

TABLE I.—Continued.

Δ	R	T	Δ	R	T	Δ	R	T
33° 0′	23.284	6.897	44° 0′	12.733	5.145	55° 0′	7.850	4.087
10′	23.043	6.862	10′	12.631	5.125	10′	7.798	4.074
20′	22.804	6.827	20′	12.530	5.105	20′	7.746	4.061
30′	22.569	6.792	30′	12.430	5.085	30′	7.695	4.048
40′	22.338	6.758	40′	12.331	5.067	40′	7.644	4.036
50′	22.110	6.725	50′	12.234	5.047	50′	7.593	4.023
34° 0′	21.886	6.691	45° 0′	12.137	5.027	56° 0′	7.543	4.011
10′	21.665	6.658	10′	12.032	5.008	10′	7.494	3.998
20′	21.447	6.625	20′	11.947	4.989	20′	7.444	3.986
30′	21.232	6.593	30′	11.854	4.971	30′	7.396	3.974
40′	21.020	6.561	40′	11.761	4.952	40′	7.347	3.962
50′	20.812	6.529	50′	11.670	4.934	50′	7.299	3.950
35° 0′	20.606	6.497	46° 0′	11.579	4.915	57° 0′	7.252	3.938
10′	20.403	6.466	10′	11.490	4.897	10′	7.205	3.926
20′	20.204	6.435	20′	11.401	4.879	20′	7.158	3.914
30′	20.007	6.404	30′	11.314	4.861	30′	7.112	3.902
40′	19.812	6.374	40′	11.227	4.843	40′	7.066	3.890
50′	19.621	6.344	50′	11.142	4.825	50′	7.021	3.878
36° 0′	19.432	6.314	47° 0′	11.057	4.808	58° 0′	6.976	3.867
10′	19.245	6.284	10′	10.973	4.790	10′	6.931	3.855
20′	19.062	6.255	20′	10.890	4.773	20′	6.887	3.844
30′	18.880	6.226	30′	10.808	4.756	30′	6.843	3.832
40′	18.702	6.197	40′	10.727	4.739	40′	6.799	3.821
50′	18.525	6.169	50′	10.646	4.722	50′	6.756	3.809
37° 0′	18.351	6.140	48° 0′	10.567	4.705	59° 0′	6.713	3.798
10′	18.180	6.112	10′	10.488	4.686	10′	6.671	3.787
20′	18.010	6.084	20′	10.410	4.671	20′	6.629	3.776
30′	17.843	6.057	30′	10.333	4.655	30′	6.587	3.765
40′	17.678	6.029	40′	10.257	4.638	40′	6.546	3.754
50′	17.515	6.003	50′	10.181	4.622	50′	6.505	3.743
38° 0′	17.355	5.976	49° 0′	10.106	4.606	60° 0′	6.464	3.732
10′	17.196	5.949	10′	10.032	4.590	10′	6.424	3.721
20′	17.040	5.923	20′	9.959	4.574	20′	6.384	3.711
30′	16.888	5.897	30′	9.887	4.558	30′	6.344	3.700
40′	16.733	5.871	40′	9.815	4.542	40′	6.305	3.689
50′	16.583	5.845	50′	9.744	4.526	50′	6.266	3.679
39° 0′	16.434	5.820	50° 0′	9.673	4.511	61° 0′	6.227	3.668
10′	16.288	5.794	10′	9.604	4.495	10′	6.188	3.658
20′	16.143	5.769	20′	9.535	4.480	20′	6.150	3.648
30′	16.000	5.745	30′	9.466	4.465	30′	6.113	3.637
40′	15.859	5.720	40′	9.399	4.449	40′	6.075	3.626
50′	15.719	5.696	50′	9.332	4.434	50′	6.038	3.616
40° 0′	15.582	5.671	51° 0′	9.265	4.419	62° 0′	6.001	3.606
10′	15.446	5.647	10′	9.200	4.404	10′	5.965	3.596
20′	15.312	5.624	20′	9.135	4.390	20′	5.928	3.586
30′	15.179	5.600	30′	9.070	4.375	30′	5.892	3.576
40′	15.045	5.576	40′	9.007	4.360	40′	5.857	3.566
50′	14.919	5.553	50′	8.943	4.346	50′	5.821	3.556
41° 0′	14.791	5.530	52° 0′	8.881	4.331	63° 0′	5.786	3.546
10′	14.665	5.507	10′	8.819	4.317	10′	5.751	3.536
20′	14.540	5.485	20′	8.758	4.303	20′	5.717	3.526
30′	14.417	5.462	30′	8.697	4.289	30′	5.682	3.516
40′	14.295	5.440	40′	8.637	4.275	40′	5.648	3.501
50′	14.175	5.418	50′	8.577	4.261	50′	5.615	3.497
42° 0′	14.056	5.396	53° 0′	8.518	4.247	64° 0′	5.581	3.487
10′	13.938	5.374	10′	8.459	4.233	10′	5.548	3.477
20′	13.822	5.352	20′	8.401	4.219	20′	5.515	3.468
30′	13.706	5.331	30′	8.344	4.206	30′	5.482	3.459
40′	13.594	5.309	40′	8.287	4.192	40′	5.450	3.450
50′	13.482	5.288	50′	8.231	4.179	50′	5.417	3.440
43° 0′	13.371	5.267	54° 0′	8.175	4.165	65° 0′	5.385	3.431
10′	13.262	5.246	10′	8.120	4.152	10′	5.354	3.422
20′	13.154	5.226	20′	8.065	4.139	20′	5.322	3.412
30′	13.047	5.205	30′	8.010	4.126	30′	5.291	3.403
40′	12.941	5.185	40′	7.957	4.113	40′	5.260	3.394
50′	12.837	5.165	50′	7.903	4.100	50′	5.229	3.385

TABLE 1.—Continued.

△	R	T	△	R	T	△	R	T
66° 0′	5.198	3.376	76° 0′	3.717	2.904	86° 0′	2.722	2.539
10′	5.168	3.367	10′	3.697	2.897	10′	2.709	2.533
20′	5.138	3.358	20′	3.678	2.891	20′	2.695	2.528
30′	5.108	3.349	30′	3.658	2.884	30′	2.681	2.522
40	5.079	3.340	40′	3.639	2.877	40′	2.668	2.517
50	5.049	3.331	50′	3.619	2.870	50′	2.655	2.512
67° 0′	5.020	3.323	77° 0′	3.600	2.864	87° 0′	2.641	2.507
10′	4.991	3.314	10′	3.581	2.857	10′	2.628	2.501
20′	4.962	3.305	20′	3.562	2.850	20′	2.615	2.496
30′	4.934	3.297	30′	3.543	2.844	30′	2.602	2.491
40′	4.905	3.288	40′	3.524	2.837	40′	2.589	2.485
50′	4.877	3.279	50′	3.506	2.830	50′	2.576	2.480
68° 0′	4.849	3.271	78° 0′	3.487	2.824	88° 0′	2.563	2.475
10′	4.822	3.263	10′	3.469	2.817	10′	2.550	2.470
20′	4.794	3.254	20′	3.450	2.811	20′	2.537	2.465
30′	4.767	3.246	30′	3.432	2.804	30′	2.525	2.460
40′	4.740	3.237	40′	3.414	2.798	40′	2.512	2.455
50′	4.713	3.229	50′	3.397	2.792	50′	2.500	2.449
69° 0′	4.686	3.221	79° 0′	3.379	2.785	89° 0′	2.487	2.444
10′	4.659	3.212	10′	3.361	2.779	10′	2.475	2.439
20′	4.633	3.204	20′	3.344	2.773	20′	2.463	2.434
30′	4.607	3.196	30′	3.326	2.766	30′	2.450	2.429
40′	4.581	3.188	40′	3.309	2.760	40′	2.438	2.424
50′	4.555	3.180	50′	3.291	2.754	50′	2.426	2.419
70° 0′	4.530	3.172	80° 0′	3.274	2.747	90° 0′	2.414	2.414
10′	4.504	3.164	10′	3.256	2.741	10′	2.402	2.409
20′	4.479	3.156	20′	3.240	2.735	20′	2.390	2.404
30′	4.454	3.148	30′	3.224	2.729	30′	2.379	2.399
40′	4.429	3.140	40′	3.207	2.723	40′	2.367	2.394
50′	4.404	3.132	50′	3.190	2.717	50′	2.351	2.390
71° 0′	4.380	3.124	81° 0′	3.174	2.711	91° 0′	2.343	2.385
10′	4.355	3.116	10′	3.157	2.705	10′	2.332	2.380
20′	4.331	3.108	20′	3.141	2.699	20′	2.320	2.375
30′	4.307	3.101	30′	3.125	2.693	30′	2.309	2.370
40′	4.283	3.093	40′	3.109	2.687	40′	2.298	2.365
50′	4.260	3.085	50′	3.093	2.681	50′	2.286	2.361
72° 0′	4.236	3.078	82° 0′	3.077	2.675	92° 0′	2.275	2.356
10′	4.213	3.070	10′	3.061	2.669	10′	2.264	2.351
20′	4.190	3.063	20′	3.045	2.663	20′	2.253	2.346
30′	4.166	3.055	30′	3.030	2.657	30′	2.242	2.342
40′	4.144	3.047	40′	3.014	2.651	40′	2.231	2.337
50′	4.121	3.040	50′	2.999	2.645	50′	2.220	2.332
73° 0′	4.098	3.033	83° 0′	2.983	2.639	93° 0′	2.209	2.328
10′	4.076	3.025	10′	2.968	2.633	10′	2.198	2.323
20′	4.054	3.018	20′	2.953	2.628	20′	2.187	2.318
30′	4.032	3.010	30′	2.938	2.622	30′	2.176	2.314
40′	4.010	3.003	40′	2.923	2.616	40′	2.166	2.309
50′	3.988	2.996	50′	2.908	2.611	50′	2.155	2.304
74° 0′	3.966	2.989	84° 0′	2.893	2.605	94° 0′	2.145	2.300
10′	3.945	2.981	10′	2.878	2.599	10′	2.134	2.295
20′	3.923	2.974	20′	2.864	2.594	20′	2.124	2.291
30′	3.902	2.967	30′	2.849	2.588	30′	2.113	2.286
40′	3.881	2.960	40′	2.835	2.583	40′	2.103	2.281
50′	3.860	2.953	50′	2.821	2.577	50′	2.093	2.277
75° 0′	3.839	2.946	85° 0′	2.806	2.571	95° 0′	2.083	2.273
10′	3.819	2.939	10′	2.792	2.566	10′	2.072	2.268
20′	3.798	2.932	20′	2.778	2.560	20′	2.062	2.264
30′	3.778	2.925	30′	2.764	2.555	30′	2.052	2.259
40′	3.757	2.918	40′	2.750	2.550	40′	2.042	2.255
50′	3.737	2.911	50′	2.736	2.544	50′	2.032	2.250

TABLE I.—Concluded.

△	R	T	△	R	T	△	R	T
96° 0′	2.022	2.246	98° 0′	1.907	2.194	100° 0′	1.799	2.145
10′	2.012	2.242	10′	1.898	2.190			
20′	2.003	2.237	20′	1.889	2.186			
30′	1.993	2.233	30′	1.880	2.182			
40′	1.983	2.229	40′	1.871	2.177			
50′	1.974	2.224	50′	1.862	2.173			
97° 0′	1.964	2.220	99° 0′	1.853	2.169			
10′	1.954	2.216	10′	1.844	2.165			
20′	1.945	2.211	20′	1.835	2.161			
30′	1.936	2.207	30′	1.826	2.157			
40′	1.926	2.203	40′	1.817	2.153			
50′	1.917	2.199	50′	1.808	2.149			

TABLE II.

Chord of 50 feet.

D	R	½d	D	R	½d	D	R	½d
8° 10′	702.18	2° 2′.42	11° 00′	521.67	2° 44′.78	14° 00′	410.28	3° 29′.61
20′	688.16	4′.92	10′	513.91	47′.3	10′	405.47	32′.1
30′	674.69	7′.43	20′	506.38	49′.8	20′	400.78	34′.6
40′	661.74	9′.91	30′	499.06	52′.3	30′	396.20	37′.1
50′	649.27	12′.43	40′	491.96	54′.8	40′	391.72	39′.6
			50′	485.05	57′.3	50′	387.34	42′.1
9° 00′	637.27	2° 14′.90						
10′	625.71	17′.39	12° 00′	478.34	2° 59′.75	15° 00′	383.06	44′.5
20′	614.56	19′.88	10′	471.81	3° 2′.3	10′	378.88	47′.0
30′	603.80	22′.38	20′	465.46	4′.8	20′	374.79	49′.5
40′	593.42	24′.87	30′	459.28	7′.3	30′	370.78	52′.0
50′	583.38	27′.37	40′	453.26	9′.8	40′	366.86	54′.5
			50′	447.40	12′.3	50′	363.02	57′.5
10° 00′	573.69	2° 29′.87						
10′	564.31	32′.4	13° 00′	441.68	3° 14′.68	16° 00′	359.26	4° 00′.0
20′	555.23	34′.9	10′	436.12	17′.2			
30′	546.44	37′.4	20′	430.69	19′.7			
40′	537.92	39′.9	30′	425.40	22′.2			
50′	529.67	42′.4	40′	420.23	24′.7			
			50′	419.19	27′.2			

Chord of 25 feet.

D	R	½d	D	R	½d	D	R	½d
			22° 00′	262.04	2° 44′.05	27° 00′	214.18	3° 20′.75
16° 10′	355.59	2° 0′.84	10′	260.10	45′.28	10′	212.89	21′.97
20′	351.98	2′.11	20′	258.18	46′.51	20′	211.62	23′.19
30′	348.45	3′.35	30′	256.29	47′.74	30′	210.36	24′.40
40′	344.99	4′.61	40′	254.43	48′.97	40′	209.12	25′.62
50′	341.60	5′.82	50′	252.60	50′.20	50′	207.89	26′.83
17° 00′	338.27	2° 7′.06	23° 00′	250.79	2° 51′.42	28° 00′	206.68	3° 28′.04
10′	335.01	8′.30	10′	249.01	52′.65	10′	205.48	29′.25
20′	331.82	9′.51	20′	247.26	53′.87	20′	204.30	30′.46
30′	328.68	10′.77	30′	245.53	55′.09	30′	203.13	31′.68
40′	325.60	12′.00	40′	243.82	56′.32	40′	201.97	32′.89
50′	322.59	13′.24	50′	242.14	57′.55	50′	200.83	34′.00
18° 00′	319.62	2° 14′.48	24° 00′	240.49	2° 58′.77	29° 00′	199.70	3° 35′.32
10′	316.71	15′.72	10′	238.85	3° 00′.00	10′	198.58	36′.53
20′	313.86	16′.95	20′	237.24	1′.21	20′	197.48	37′.74
30′	311.06	18′.18	30′	235.65	2′.44	30′	196.38	38′.95
40′	308.30	19′.42	40′	234.08	3′.66	40′	195.31	40′.16
50′	305.60	20′.65	50′	232.54	4′.88	50′	194.24	41′.37
19° 00′	302.94	2° 21′.89	25° 00′	231.01	3° 6′.11	30° 00′	193.19	3° 42′.58
10′	300.33	23′.09	10′	229.51	7′.33	10′	192.14	43′.79
20′	297.77	24′.35	20′	228.02	7′.55	20′	191.11	45′.00
30′	295.25	25′.59	30′	226.55	9′.78	30′	190.09	46′.22
40′	292.77	26′.82	40′	225.11	11′.00	40′	189.08	47′.43
50′	290.33	28′.06	50′	223.68	12′.22	50′	188.09	48′.64
20° 00′	287.94	2° 29′.29	26° 00′	222.27	3° 13′.43	31° 00′	187.10	3° 49′.84
10′	285.58	30′.52	10′	220.88	14′.65	10′	186.12	51′.05
20′	283.27	31′.75	20′	219.51	15′.87	20′	185.16	52′.26
30′	280.99	32′.98	30′	218.15	17′.09	30′	184.20	53′.47
40′	278.75	34′.21	40′	216.81	18′.31	40′	183.26	54′.68
50′	276.54	35′.44	50′	215.49	19′.53	50′	182.32	51′.89
21° 00′	274.37	2° 36′.67						
10′	272.23	37′.91						
20′	270.13	39′.13						
30′	268.08	40′.36						
40′	266.02	41′.59						
50′	264.02	42′.82						

TABLE II.—Continued.

Chord of 10 feet.

D	R	½d	D	R	½d	D	R	½d
32° 00′	181.40	1° 34′.77	42° 00′	139.52	2° 3′.22	52° 00′	114.06	2° 30′.75
10′	180.48	35′.25	10′	138.99	3′.69	10′	113.72	31′.30
20′	179.58	35′.73	20′	138.47	4′.16	20′	113.38	31′.75
30′	178.68	36′.21	30′	137.96	4′.63	30′	113.05	32′.10
40′	177.79	36′.69	40′	137.44	5′.09	40′	112.72	32′.55
50′	176.92	37′.17	50′	136.93	5′.55	50′	112.39	33′.00
33° 00′	176.05	1° 37′.65	43° 00′	136.43	2° 6′.02	53° 00′	112.06	2° 33′.44
10′	175.19	38′.13	10′	135.92	6′.49	10′	111.73	33′.89
20′	174.34	38′.61	20′	135.43	6′.96	20′	111.41	34′.34
30′	173.49	39′.09	30′	134.93	7′.42	30′	111.09	34′.78
40′	172.66	39′.57	40′	134.44	7′.78	40′	110.77	35′.33
50′	171.83	40′.05	50′	133.96	8′.14	50′	110.45	35′.78
34° 00′	171.02	1° 40′.53	44° 00′	133.47	2° 8′.78	54° 00′	110.13	2° 36′.12
10′	170.21	41′.01	10′	132.99	9′.25	10′	109.82	36′.57
20′	169.40	41′.49	20′	132.52	9′.72	20′	109.51	37′.02
30′	168.61	41′.96	30′	132.05	10′.20	30′	109.20	37′.46
40′	167.82	42′.44	40′	131.58	10′.66	40′	108.90	37′.91
50′	167.05	42′.92	50′	131.12	11′.12	50′	108.59	38′.36
35° 00′	166.28	1° 43′.39	45° 00′	130.66	2° 11′.59	55° 00′	108.28	2° 38′.79
10′	165.51	43′.87	10′	130.20	12′.05	10′	107.98	39′.24
20′	164.76	44′.35	20′	129.75	12′.51	20′	107.68	39′.69
30′	164.01	44′.82	30′	129.30	12′.98	30′	107.38	40′.13
40′	163.27	45′.30	40′	128.85	13′.44	40′	107.09	40′.57
50′	162.53	45′.78	50′	128.41	13′.90	50′	106.80	41′.01
36° 00′	161.80	1° 46′.25	46° 00′	127.96	2° 14′.36	56° 00′	106.50	2° 41′.45
10′	161.08	46′.73	10′	127.53	14′.82	10′	106.21	41′.89
20′	160.37	47′.21	20′	127.09	15′.28	20′	105.92	42′.33
30′	159.66	47′.68	30′	126.66	15′.74	30′	105.64	42′.78
40′	158.96	48′.16	40′	126.24	16′.20	40′	105.35	43′.22
50′	158.27	48′.64	50′	125.81	16′.66	50′	105.07	43′.66
37° 00′	157.58	1° 49′.11	47° 00′	125.39	2° 17′.12	57° 00′	104.79	2° 44′.10
10′	156.90	49′.58	10′	124.97	17′.58	10′	104.51	44′.54
20′	156.22	50′.05	20′	124.56	18′.04	20′	104.23	44′.98
30′	155.55	50′.53	30′	124.14	18′.50	30′	103.95	45′.42
40′	154.89	51′.00	40′	123.74	19′.96	40′	103.68	45′.86
50′	154.23	51′.47	50′	123.33	20′.42	50′	103.40	46′.30
38° 00′	153.58	1° 51′.94	48° 00′	122.93	2° 19′.86	58° 00′	103.13	2° 46′.73
10′	152.93	52′.41	10′	122.53	20′.32	10′	102.86	47′.17
20′	152.29	52′.88	20′	122.12	20′.78	20′	102.59	47′.61
30′	151.66	53′.36	30′	121.74	21′.24	30′	102.33	48′.04
40′	151.03	53′.83	40′	121.35	21′.70	40′	102.06	48′.48
50′	150.41	54′.30	50′	120.96	22′.16	50′	101.80	48′.92
39° 00′	149.79	1° 54′.78	49° 00′	120.57	2° 22′.60	59° 00′	101.54	2° 49′.35
10′	149.17	55′.25	10′	120.19	23′.06	10′	101.28	49′.79
20′	148.57	55′.72	20′	119.81	23′.52	20′	101.02	50′.23
30′	147.97	56′.19	30′	119.43	23′.97	30′	100.76	50′.66
40′	147.37	56′.66	40′	119.05	24′.42	40′	100.51	51′.10
50′	146.78	57′.13	50′	118.68	24′.87	50′	100.25	51′.54
40° 00′	146.19	1° 57′.60	50° 00′	118.31	2° 25′.33	60° 00′	100.00	2° 51′.96
10′	145.61	58′.07	10′	117.94	25′.78	10′	99.75	52′.40
20′	145.03	58′.54	20′	117.58	26′.23	20′	99.50	52′.84
30′	144.46	59′.01	30′	117.21	26′.69	30′	99.25	53′.26
40′	143.89	59′.48	40′	116.85	27′.14	40′	99.00	53′.69
50′	143.33	59′.95	50′	116.50	27′.59	50′	98.78	54′.12
41° 00′	142.79	2° 00′.44	51° 00′	116.14	2° 28′.05	61° 00′	98.51	2° 54′.55
10′	142.22	00′.90	10′	115.79	28′.50	10′	98.27	54′.98
20′	141.69	1′.36	20′	115.44	28′.95	20′	98.03	55′.41
30′	141.13	1′.82	30′	115.09	29′.40	30′	97.79	55′.84
40′	140.59	2′.28	40′	114.74	29′.85	40′	97.55	56′.27
50′	140.05	2′.74	50′	114.40	30′.30	50′	97.32	56′.70

TABLE II—Continued.

D	R	½d	D	R	½d	D	R	½d
62° 00′	97.08	2° 57′.14	72° 00′	85.07	3° 22′.18	82° 00′	76.21	3° 45′.70
10′	96.85	57′.57	10′	84.90	22′.59	10′	76.09	46′.08
20′	96.61	58′.00	20′	84.73	23′.00	20′	75.96	46′.46
30′	96.38	58′.42	30′	84.56	23′.40	30′	75.83	46′.83
40′	96.15	58′.85	40′	84.39	23′.80	40′	75.71	47′.21
50′	95.92	59′.28	50′	84.22	24′.20	50′	75.58	47′.59
63° 00′	95.69	2° 59′.70	73° 00′	84.06	3° 24′.61	83° 00′	75.46	3° 47′.96
10′	95.47	60′.13	10′	83.89	25 .01	10′	75.33	48′.33
20′	95.24	60′.56	20′	83.73	25′.41	20′	75.21	48′.70
30′	95.02	3° 00′.98	30′	83.57	25′.81	30′	75.09	49′.08
40′	94.80	01′.41	40′	83.40	26′.21	40′	74.97	49′.45
50′	94.57	01′.84	50′	83.24	26′.61	50′	74.84	49′.82
64° 00′	94.35	3° 02′.26	74° 00′	83.08	3° 27′.01	84° 00′	74.72	3° 50′.20
10′	94.14	02′.68	10′	82.92	27′.41	10′	74.60	50′.57
20′	93.92	03′.10	20′	82.76	28′.81	20′	74.48	50′.94
30′	93.70	03′.53	30′	82.60	28′.21	30′	74.36	51′.32
40′	93.49	03′.95	40′	82.45	28′.61	40′	74.25	51′.69
50′	93.27	04′.37	50′	82.29	29′.01	50′	74.13	52′.06
65° 00′	93.06	3° 04′.80	75° 00′	82.13	3° 29′.41	85° 00′	74.01	3° 52′.43
10′	92.85	05′.22	10′	81.98	29′.81	10′	73.89	52′.80
20′	92.64	05′.64	20′	81.82	30′.20	20′	73.78	53′.17
30′	92.43	06′.07	30′	81.67	30′.60	30′	73.66	53′.53
40′	92.22	06′.49	40′	81.52	31′.99	40′	73.54	53′.90
50′	92.01	06′.91	50′	81.37	32′.39	50′	73.43	54′.27
66° 00′	91.80	3° 07′.33	76° 00′	81.22	3° 31′.78	86° 00′	73.31	3° 54′.64
10′	91.60	07′.75	10′	80.07	32′.17	10′	73.20	55′.00
20′	91.39	08′.17	20′	80.91	32′.57	20′	73.09	55′.36
30′	91.19	08′.58	30′	80.76	32′.97	30′	72.97	55′.73
40′	90.99	09′.00	40′	80.61	33′.36	40′	72.86	56′.10
50′	90.79	09′.42	50′	80.47	33′.75	50′	72.75	57′.47
67° 00′	90.59	3° 09′.83	77° 00′	80.32	3° 34′.15	87° 00′	72.64	3° 56′.83
10′	90.39	10′.25	10′	80.17	34′.54	10′	72.53	57′.20
20′	90.19	10′.67	20′	80.03	34′.93	20′	72.42	57′.56
30	90.00	11′.09	30′	79.88	35′.32	30′	72.31	57′.92
40′	89.80	11′.51	40′	79.74	35′.71	40′	72.20	58′.28
50′	89.61	11′.93	50′	79.59	36′.10	50′	72.09	58′.66
68° 00′	89.41	3° 12′.34	78° 00′	79.45	3° 36′.49	88° 00′	71.98	3° 59′.00
10′	89.22	12′.75	10′	79.31	36′.89	10′	71.87	59′.35
20′	89.03	13′.16	20′	79.17	37′.29	20′	71.76	59′.70
30′	88.84	13′.58	30′	79.03	37′.70	30′	71.65	4° 00′.06
40′	88.65	13′.99	40′	78.89	38′.10	40′	71.55	00′.42
50′	88.46	14′.40	50′	78.75	38′.50	50′	71.44	00′.78
69° 00′	88.28	3° 14′.82	79° 00′	78.61	3° 38′.81	89° 00′	71.34	4° 01′.15
10′	88.09	15′.23	10′	78.47	39′.20	10′	71.23	01′.51
20′	87.90	15′.64	20′	78.33	39′.59	20′	71.13	01′.87
30′	87.72	16′.06	30′	78.19	39′.97	30′	71.02	02′.22
40′	87.54	16′.47	40′	78.06	40′.36	40′	70.92	02′.68
50′	87.35	16′.88	50′	77.92	40′.75	50′	70.81	03′.14
70° 00′	87.17	3° 17′.29	80° 00′	77.79	3° 41′.13	90° 00′	70.71	4° 03′.29
10′	86.99	17′.70	10′	77.65	41′.51	10′	70.61	03′.64
20′	86.81	18′.11	20′	77.52	41′.89	20′	70.51	03′.99
30′	86.63	18′.52	30′	77.38	42′.28	30′	70.40	04′.35
40′	86.46	18′.93	40′	77.25	42′.66	40′	70.30	04′.70
50′	86.28	19′.34	50′	77.12	43′.04	50′	70.20	05′.05
71° 00′	86.10	3° 19′.74	81° 00′	76.99	3° 43′.42	91° 00′	70.10	4° 05′.41
10′	85.93	20′.15	10′	76.86	43′.80	10′	70.00	05′.76
20′	85.75	20′.56	20′	76.73	44′.18	20′	69.90	06′.11
30′	85.58	20′.97	30′	76.60	44′.57	30′	69.80	06′.46
40′	85.41	21′.37	40′	76.47	44′.95	40′	69.71	06′.81
50′	85.24	21′.78	50′	76.34	45′.33	50′	69.61	07′.16

TABLE II.—Concluded.

D	R	½d	D	R	½d	D	R	½d
92° 00′	69.51	4° 07′.51	95° 00′	67.82	4° 13′.69	97° 00′	66.76	4° 17′.72
10′	69.41	07′.86	10′	67.73	14′.03	10′	66.67	18′.05
20′	69.31	08′.12	20′	67.64	14′.37	20′	66.59	18′.38
30′	69.22	08′.55	30′	67.55	14′.70	30′	66.51	18′.70
40′	69.12	08′.90	40′	67.46	15′.04	40′	66.42	19′.03
50′	69.03	09′.24	50′	67.37	15′.38	50′	66.33	19′.36
93° 00′	68.93	4° 09′.58	96° 00′	67.28	4° 15′.71	98° 00′	66.25	4° 19′.70
10′	68.83	09′.93	10′	67.19	16′.04	10′	66.17	20′.03
20′	68.74	10′.28	20′	67.10	16′.37	20′	66.08	20′.36
30′	68.65	10′.63	30′	67.02	16′.71	30′	66.00	20′.68
40′	68.55	10′.96	40′	66.93	17′.04			
50′	68.46	11′.30	50′	66.85	17′.38			
94° 00′	68.37	4° 11′.64						
10′	68.27	11′.98						
20′	68.18	12′.32						
30′	68.09	12′.67						
40′	68.00	13′.01						
50′	67.91	13′.35						

TABLE III.—Minutes in Decimals of a Degree.

1′	.0167	11′	.1833	21′	.3500	31′	.5167	41′	.6833	51′	.8500
2	.0333	12	.2000	22	.3667	32	.5333	42	.7000	52	.8667
3	.0500	13	.2167	23	.3833	33	.5500	43	.7167	53	.8833
4	.0667	14	.2333	24	.4000	34	.5667	44	.7333	54	.9000
5	.0833	15	.2500	25	.4167	35	.5833	45	.7500	55	.9167
6	.1000	16	.2667	26	.4333	36	.6000	46	.7667	56	.9333
7	.1167	17	.2833	27	.4500	37	.6167	47	.7833	57	.9500
8	.1333	18	.3000	28	.4667	38	.6333	48	.8000	58	.9667
9	.1500	19	.3167	29	.4833	39	.6500	49	.8167	59	.9833
10	.1667	20	.3333	30	.5000	40	.6667	50	.8333	60	1.0000

TABLE IV.—Inches in Decimals of a Foot.

1–16	3–32	1/8	3–16	1/4	5–16	3/8	1/2	5/8	3/4	7/8
.0052	.0078	.0104	.0156	.0208	.0260	.0313	.0417	.0521	.0625	.0729
1	2	3	4	5	6	7	8	9	10	11
.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167